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Strategies for Aquaculture Development in Canada

St. Andrews, New Brunswick, July 10–14, 1983

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PREFACE

Technology is one of the major driving forces behind the restructuring of many economies. In the early 1980s, attention in Canada turned to policies promoting economic growth including the policy shift from "science" to the related domain of technology. The aim was to develop a framework within which technological innovation could flourish, where long-term planning and risk-taking were encouraged and rewarded, and within which technology transfer from abroad could enrich the sectors of our economy which needed to become more internationally competitive. Recognition of the primacy of the business sector in initiating innovation and new investment, in collaboration with government and university sectors was also imperative.

Success in renewing segments of the economy depends to a great extent upon success in managing technology. In the fisheries sector, aquaculture is an excellent case study; yields are determined by the inputs of technology, skills, and investment rather than upon the productivity of the natural resource. One could only surmise the extent to which these policies were perceived as relevant or even known by those most affected. Thus, a National Aquaculture Conference held in 1983 under joint sponsorship of the Department of Fisheries and Oceans and the Science Council of Canada provided a timely review of the status of aquaculture in seeking alternative and more intensive production systems for finfish, shellfish, crustaceans, and marine plants. The keynote address and background papers of this Conference constitute this publication.

Conference planners ensured that these papers were of Canadian origin in keeping with a desire to obtain an accurate reflection of Canadian industry and its opportunities. No attempt was made to formally compare Canadian developments with those elsewhere, or to present official statements or a preconceived advocacy. Attention was given to strategic planning, possibly at the expense of site-specific tactics upon which campaigns to improve practices must focus. This led to some undue attention as to how governments might act as catalysts for private sector initiatives. Nevertheless, readers will find a wealth of information in these papers, and the unique aspects of aquaculture in Canada will be more readily apparent.

Several characteristics of the industry emerge. Diversity will be obvious, and concerns for compatibility with wild resources are prominent. Structure of the industry can best be described as clustered around subregional economic needs, geographic features, and indigenous species or those already introduced, and often occurs in close proximity to research centres such as St. Andrews, New Brunswick, where the Conference was held. Few turn-key technologies are available; the need for industrial research and experimental development is still extensive. Essential infrastructures and the allied supply industries are at various stages of implementation. Market information has been lacking, although production and technical uncertainties still dominate the concerns of those already involved in the industry. Also, as the future structure of aquaculture operations can now be fixed, it is timely to revise the regulatory framework. A more proactive role for governments was advocated.

Success of either the Conference or the industry is difficult to measure at this point in time. Clearly, many of the elements in which expansion can occur are already in place. Public awareness of opportunities has been awakened, and interest runs high. Investment decisions are being made, often with long-range objectives that will not have an impact upon production statistics for some time. Concerns of those pioneering the industry often differ from those seeking to extend intensive husbandry practices to new production systems or to districts of the country which have few aquaculture traditions. Uncertainties as to the ability of selected segments of the industry to sustain development without governmental assistance also emerge, as do questions on distribution of benefits and to what extent aquaculture might be called upon to offset the costs of technological change to those disadvantaged elsewhere in the fisheries.

In any case, much appreciation and gratitude is due to those whose unsparing efforts led to the preparation of these papers. For further information regarding the Conference structure, attendance, and conclusions from the various theme sessions, readers should refer to the "Report of the Proceedings of the National Aquaculture Conference," published earlier (available from the Department of Fisheries and Oceans, Fisheries Research Directorate, Aquaculture and Resource Development Branch, 200 Kent Street, 12th Floor, Ottawa, Ontario K1A 0E6).

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KEYNOTE ADDRESS

AQUACULTURE IN CANADA: GETTING OUR ACT TOGETHER

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Recent growth in world aquaculture production has been related to four main causes: advances in science and technology, population pressures, a levelling-off of capture fisheries production, and disruption of traditional patterns of supply and demand caused by the proclamation of 200-mile Exclusive Economic Zones by most of the world's coastal states.

Canada's prospects are examined in relation to assets including water supplies, expertise, the existence of effective fish health regulations, and supplies of fish food. Opportunities within Canada vary from region to region so that regional aquaculture development could be complementary rather than competitive. Priority needs in Canada are long-term cooperative research and development, training, investment capital, and the development of a coherent legal framework — this latter aim to be pursued in a pragmatic and cooperative way by the jurisdictions involved.

I wish to thank the organizers of this Conference for giving all of us involved in aquaculture, directly or indirectly across Canada, this chance to get together under one roof. Personally for many of us it's an opportunity to renew old friendships. Professionally the opportunity to meet and exchange views couldn't come at a better time. The last time aquaculture was discussed at a national meeting was in Winnipeg, in June 1973 — as part of a series of consultations with industry and provincial representatives on fisheries development strategy in Canada. Bob Martin and Ian Pritchard organized it, I believe — and I was chairman. Hugh McCrimmon, Roly Brett, and Jim Stewart backgrounded the discussions with papers on prospects and needs. It will be fascinating to compare our results on Thursday noon here at this meeting with the report of that 1973 meeting.

This conference has been called for many reasons. The most basic one is that for aquaculture and the people in it, this is a time of transition. Here in Canada, and throughout the world, an ancient industry has suddenly become new. After thousands of years of tagging along as a sort of auxiliary to the capture fisheries, aquaculture has become a dynamic growth sector in the world's fish producing industry.

I have entitled my talk "Aquaculture in Canada: Getting our Act Together" and I plan to review our situation in a world context, look at the factors influencing it, and suggest our future course.

Industrial statistics make dull reading and it takes a foolhardy speaker to use very many of them. But in this case they describe a revolution. Between 1975 and 1980, aquacultural production throughout the world increased by 42% (Table 1). And Table 2 conceals even greater gains — crustaceans for instance, up 455% in the same period. During this time frame, the aggregate landing totals of the world capture fisheries were virtually unchanged.

In 1980, according to some highly respected experts, world aquaculture production totalled about 8 million tonnes, over 10% of total world commercial fish production of about 73 million tonnes. By the year 2000, some experts tell us world production of cultured fish could be as high as 15 million tonnes. Asia and Europe are where it's at in aquaculture production — production on the other continents is relatively insignificant (Table 3 and 4). This probably reflects the concentrated demand from large populations.

Meanwhile, the production from the capture fisheries is bumping against the ceiling – at least for species we exploit today. In short, aquaculture in the world is experiencing a boom (Table 4). And that of course is one reason for this gathering. We want to examine this new situation and see how it relates to our affairs here in Canada. We want to

TABLE 1. Total world aquaculture production: all species.

Year	World production
1967	1 000 000 tonnes
1970	2 600 000 tonnes
1973	5 000 000 tonnes
1975	6 100 000 tonnes
1980	8 700 000 tonnes

TABLE 2. Total world aquaculture production: crustaceans

Year	World production
1967	3 000 tonnes
1970	7 800 tonnes
1973	15 000 tonnes
1975	15 600 tonnes
1980	71 200 tonnes

TABLE 3. Regional aquaculture production.

Region	%
Africa	0.05%
Latin America	0.86%
North America	1.61%
Europe	13.05%
Asia	84.43%

TABLE 4. Comparison of aquaculture producers 1980.

Country	Production
Canada	4 600 tonnes
USA	135 400 tonnes
Korea	481 000 tonnes
India	848 000 tonnes
Japan	976 000 tonnes
China	4 000 000 tonnes

discuss and recommend what the industry needs to do to make the most of its new opportunities.

The self-evident answer is that new factors are in play. First in importance is the flowering of aquaculture itself. Advances in its science, technology, and economics have been made on a very broad front. And the steady rise of demand for fish products worldwide along with price increases higher than many other food products has made aquaculture development opportunities more attractive as a commercial venture.

An important driving force is the pressure of rapidly increasing populations on food supplies. The world needs protein and at present receives about 24% of its animal protein from fish.

A third factor is the inexorable approach to the ceiling of world capture fishery production. This prospect has persuaded many nations and entrepreneurs to wake up and start thinking original thoughts about how to meet future world demand for animal protein.

The fourth factor is the 200-mile fishing limit. Many nations which once relied on distant water fleets for fish supplies have been cut off from these sources. Whether coastal states like it or not these nations are not necessarily going to accept dependency. Many have turned their attention to aquaculture with renewed interest. They see it as a way to make up some of their losses with minimum damage to their trade balance situations. Japan is an excellent example of the influence of this factor.

These are the four key underlying factors influencing our development.

The biggest single difference between capture fisheries and aquaculture is *property rights* — and I believe that difference will have a profound affect on the future of aquaculture.

Aquaculture isn't based on a common property resource. That gives it an immense advantage over the capture fisheries in many cases, despite the new Exclusive Economic Zones. There is no question of a free-for-all, and thus there is less confusion about rights, responsibilities, and rewards. A fisheries economist and ex-colleague of mine from FAO and DFO, Dr. Chris Newton, has pointed out that a trigger for the revolution in agriculture for livestock development in the 18th century was the Enclosures Act and the fencing in of common pastures. This led to the establishment of private property rights and allowed the development of the industry. Coupled with demand stimulated by the industrial revolution, it resulted in the birth of modern agriculture with its vastly more efficient techniques. The operating stimuli seem to have been the same ones we're seeing in the fisheries today.

How do these trends affect us in Canada? At this point we certainly are not in the big league of aquaculture. In terms of volume we're producing in the range of 2000–5000 tonnes of fish a year — about $6 million worth of product from culture operations for food. But in Canada and everywhere else you have to be a bit careful about aquaculture production statistics: just ask my former colleague, Ian Pritchard, who tries to keep track of these things.

Looking back at where we've been compared to the rest of the world doesn't make our prospects look very bright. But, let's put this information aside and explore our Canadian assets.

Let's look first at the natural advantages.

The topsoil for this kind of farming is water. We're blessed with more than our share of that resource — and our assets include an abundance of inland systems, productive estuaries, and large areas of sheltered coastline. And, in contrast with most industrialized nations, most of these resources are still not endangered by pollution or other settlement pressures.

We are limited by some natural constraints. A fish farmer in Canada faces certain challenges his counterpart in a tropical or subtropical country wouldn't encounter. But the impacts are not all negative. In some cases, for instance in raising scallops, climate is on our side. And anyway, one happy characteristic of aquaculture is that this is a form-fitting industry. In a relatively dry middle-eastern country, it may be distinguished by the development of systems that economize dramatically on water. The Canadian adaptation is more likely to produce innovation in cold water systems, or systems that make use of warm industrial waste waters. On questions of climate and opportunity we should compare ourselves not with a tropical country but with another northern nation. Canada is a very large Norway. And if Norway is indeed fighting an uphill battle against an unfavourable aquacultural environment it must be a triumph over the laws of gravity.

Another Canadian asset and one that is particularly relevant to modern aquaculture is know-how. The fishing and agricultural industries are important in this country. One result of this is that we have developed a solid corps of expertise in disciplines related to aquaculture — marine biology for instance, fisheries management, animal husbandry, and fisheries economics. A large number of fisheries experts from developing countries where their fishery and aquaculture industries outstrip ours, have received their formal training in Canada from our centres of knowledge.

A third, and less visible advantage we have is derived, I believe, from our status as a major sport fishing nation. That fishery depends also on aquaculture, and what is common between these entreprises and the commercial food fish farmer is concern about fish disease. Canada's federal fish health regulations have been in place for 6 years, and they are generally recognized as models for other nations. To someone outside the industry this may seem to be a minor administrative advantage. People within the industry know otherwise. Introduction of fish diseases is probably the greatest fear of the fish farmer. The presence of such regulations reduce that risk, and they make it easier to obtain capital for development.

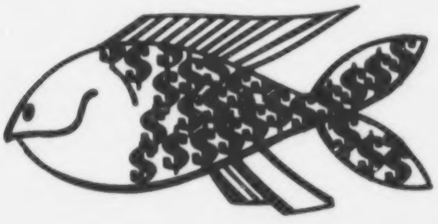
Another asset we have is our home supply of fish food. We've gone from importing 90% of our fish food 10 years ago to less than 20% today through the development of our own fish feed industry. So we should be able to have reliable supplies of feed in Canada into the future.

Let's broaden the discussion now to include opportunities — reasons, inducements for Canadians to take aquaculture seriously, not only from the viewpoint of individual operators but in terms of the national interest.

One way to define the potential of aquaculture in Canada is with reference to the opportunities and limitations now confronting our traditional capture fishing industry.

Historically — one might say from Confederation through to Michael Kirby and Peter Pearse — the will o'the wisp goal of fisheries management in Canada has been resource and economic stability. As my ex-boss, the Hon. Romeo LeBlanc used to remind the public, a fisherman's life can be an adventure but there's plenty of nightmare in it too. The industry is essentially at the mercy of nature and nature has often been cruel. Witness the collapse from time to time of many important fisheries. Aquaculture tends to be less of a gambler's game as far as supply is concerned. It isn't limited by the size of a natural resource base. It's not driven by tides and upwellings, but by skills and science. I don't mean to suggest that it's self-regulating. The laws of economics certainly apply — markets must still exist or be brought into existence, management must still be competent. But by and large there are not as many wild cards in the deck. You will have to beat the bushes for markets and customers. But you don't lie awake wondering if when the customers meet you on the dock you'll have a product to sell.

Modern aquaculture possesses another built-in stabilizer: the chance for product quality control. Its specialty, in fact, is a species you won't find in the FAO Atlas of World Fisheries or any other directory. Its Latin name is *Pisces Pecuniaris*. In English it's "The Money Fish," the ultimately profitable product. The capture fisheries cannot always count on the Money Fish. Aquaculturists usually can, if they manage things right. In fisheries, if a high product quality is not maintained, *Pisces Pecuniaris* loses his green scales very quickly!



Pisces Pecuniaris

It is possible for aquaculturists today to grow their product the way a farmer does, from spawning to harvest, manipulating produce size, texture, colour, and delivery time to market. Sea ranchers opt for somewhat less control but even they have eliminated some of the variables with which the capture fisheries contend. And we are still skimming the surface in improving resistance to disease, accelerating growth rates and custom tailoring of desire characteristics.

The quality advantage that cultured fish bring to the market is demonstrated every day of the year, and some of the demonstrations occur uncomfortably close to home. Cultured salmon from Norway compete with Pacific salmon in Europe, which is perhaps not surprising, but also in Seattle, Washington, which certainly is. Norwegian salmon competes not because it's cheaper but because it is considered by many to be better. I think it's necessary to emphasize this aspect because outside the industry the superiority of the cultured product is not yet understood. Thor Micwelson is the Norwegian aquaculturist who pioneered this industry and whose company is now responsible for 10% of Norway's salmon production. He recalls that when he first went looking for investment money he found it tough going. His bankers assumed a cultured salmon would be inferior to the wild variety.

Aquaculture can help stabilize and complement fisheries in other ways. Stocks that have been overfished, or depleted in other ways can in some cases be reinforced by infusions of cultured fish. (As obvious example of this is Salmonid Enhancement Program on the Pacific Coast.) In other cases, where buyers are still lined up for a given species but fishing has been stopped for management reasons, aquaculture can sometimes fulfill the demand without violating management limits.

Aquaculture can also expand existing opportunities and create new product lines. For example, on the west coast projects are underway to culture sable fish. If it works out it will be possible to market sable 12 months a year. Better still it will be possible to offer sable at exactly the right size for the Japanese market.

These are immediate, visible benefits. There are some less obvious but still tangible ones.

As someone who has worked a good part of his lifetime in fisheries development and environmental protection, I've learned that although many industries claim to be environmentally benign, the presence of healthy fish is the best proof of a healthy environment. What's good for fish is good for the aquatic environment.

In other words it can be a highly convincing argument for protecting an ecosystem. From the viewpoint of the industry this means an advantage in the competition for water uses. From the viewpoint of society it means a chance to eat your economic cake and have it too. With good management — holistic management — we could look at ecosystems and coordinate not one but many uses. There's nothing revolutionary about this concept. The Japanese have been quietly practicing it in their prefecture system for over a century. The introduction of a profitable aquaculture operation into a given ecosystem, an estuary for instance, would impose upon us the discipline of holistic management. Environmentally and economically we would all be richer for it.

Finally the most basic inducement of all. Aquaculture in the hands of organized and resourceful people can be an economically profitable operation. As an FAO study points out, investors in large-scale capture fisheries in the Philippines earn an average of 11% on their investment while some investors in aquaculture there get better than 60%. The equations in northern climates may be different but these figures should be food for thought.

In zeroing in on specific Canadian opportunities it's reassuring to note that each region has its own opportunities. Aquaculture in Canada will likely continue to develop as a mosaic in which industry in one region complements rather than competes with that in another.

Newfoundland for instance has opportunities for seawater culture but is not so well off on the freshwater side. So its big hopes are in coldwater technology and the raising of species such as scallop. To use a Japanese unit of comparison, it would be a Canadian Hokkaido.

In Prince Edward Island where the saltwater's a little warmer, the opportunities probably lie in the area of lobster holding and culture and the cultivation of marine plants.

In Nova Scotia there are opportunities from Cape Breton to the southern shore. Cultivation of oysters and mussels for instance. Here in New Brunswick, scientists have been focussing with particular interest on Kennebacasis Bay, a brackish, estuarine environment opening on the Saint John River. The feeling is that because of water chemistry and temperature this is an excellent site for year-round commercial culture of Atlantic salmon and other salmonids.

Moving into Quebec and Ontario, one major asset is the market. There are opportunities to expand sales of cultured fish, fresh as well as frozen, into the Montreal, Toronto, and associated markets. And, as highly industrialized provinces, Quebec and Ontario have other untapped inputs in the form of heated water from thermal electric power plants and other installations. The interesting thing about these areas is that there are domestic markets here ready for recapture. Sixty-six percent of Canada's imports of trout go into Ontario. Even if one half of these imports wind up on dinner tables in the province itself, Ontario aquacultural operators could use their geographic advantage to make important gains.

On the prairies that major product today is trout but there are wider possibilities including pickerel. Agriculture is another prairie advantage. Fish feed, from plant protein, could be developed close to production sites. Another possibility that has been talked about is the chance to use waste heat from pumping stations on oil and gas pipe lines as these expand across the prairie.

British Columbia offers a variety of opportunities in both saltwater and freshwater including sea farming of black cod and herring, to say nothing of the possibilities of culturing a whole range of Pacific salmon. There's some important work on scallop culture in progress at the Pacific Biological Station in Nanaimo. The B.C. and federal governments are trying to find out if scallop, notably the Japanese species, can be cultured commercially in B.C. If this work succeeds, it might result in the development of an important new industry.

So our opportunities are real, but elusive, nonetheless. They won't be realized without effort — the conditions for doing so have to be created.

Here are some of the issues we need to address most urgently.

First, we need a committed well-funded long-term research and development effort on the part of governments, *and* the private sector. The rationale for such a cooperative effort is basically the same as that which justified public sector Research and Development (and it has been extensive) for prairie agriculture. That investment over a period of years helped make Canadian agriculture one of the world's most productive. The biggest players in aquaculture, including Japan and Norway, have followed a policy of strong support from government not only in research but in other areas. We need well-funded *long-term* studies, concentrated on the most promising candidate species or opportunities. Like other countries we also need to make better use of what we know, to close the gap between what aquaculture does and what it could do.

In this connection I must take note of the superb service rendered to this industry by Canada's delegation to the international conference on Technology, Growth and Employment, which convened in Versailles last year.

This conference, as you may know, involved heads of governments of the European Economic Community and seven national governments. It recommended projects in four major areas. One of Canada's proposals was for collaborative work in aquaculture, specifically the development and adaptation of coldwater techniques for production of fish, shellfish, and marine plants. Canadian aquaculture, I'm sure, welcomes this evidence of government's sensitivity to the opportunities and priorities in this industry. And it owes a vote of thanks to Dr. Pritchard and his colleagues at the Department of Fisheries and Oceans for their work on assembling the proposal, and to the Canadian delegation, headed by Dr. Larkin Kerwin of the National Research Council, for the skill with which it presented it to the Conference.

To continue the list of needs, we require a more focused and coordinated effort in training. Individual and separate programs are in place covering many related disciplines at various institutions. By and large the universities, technology institutes, and community colleges of our country have not taken a comprehensive approach to the teaching of aquaculture. There are some exceptions — Malaspina College in B.C. offers a 2-year technical course in aquaculture. Here, as in so many other areas, there is much to be gained by getting our act together.

There's a need for capital. Aquaculturists can have an attractive proposition to offer investors. Science and technology keep lowering the risks and the costs while world conditions tend to improve the market. These selling points need to be merchandized to investors. And I'd like to take this opportunity to do some merchandizing to a specific group of potential investors — the people in Canada's fishing industry. Aquaculture is a natural extension of the industry — the real name of the game after all is not lines, nets, and hooks, but *fish*. By virtue of experience with the end product, no group is better equipped to capitalize on the opportunities in aquaculture. This being the case I find it remarkable that fishermen and fishing companies have not shown a greater interest in this field. It's a natural fit.

There's another need, one which Canada shares with every other aquaculturally developing nation. I'm talking about the establishment of a legal framework — a set of ground rules — which takes into account the growing presence of aquaculture. That legal framework needs to be based on complementary national and provincial policy positions.

In this country all questions, large and small, eventually seem to come down to that of jurisdiction.

It's true that aquaculture presents some particularly complicated versions of this classic Canadian dilemma. But there's a trap here we must make every effort to avoid. The fact that jurisdictional questions are raised doesn't mean that aquaculture requires nothing less than a revolution of jurisdictions. What the industry needs isn't a prolonged debate about responsibilities but agreement on some basic principles.

One is that the governments involved opt for teamwork and adaptation in ironing out these contradictions. No one, the industry least of all, can afford a jurisdictional tug of war.

A second is to make sure that in attempting to simplify the situation, we don't wind up complicating it. We don't need a new bureaucracy to oversee aquaculture.

A third is that whatever adaptations and responses we do come up with relate to real problems and real conditions. That, in case you're not reading me, is a plea for responses developed in collaboration with the industry, with continuing inputs from working aquaculturists. In this spirit we should be able to cope with many urgent questions we now face — decisions about lease and licence procurement, measures to protect cultured and wild stocks from negative interaction, questions of international coordination and cooperation.

A final basic need for individual companies and for the industry as a whole is to get out there and sell. Having a good product doesn't guarantee that you'll find a market. In order to balance the books aquaculture's production costs must be met by creating and maintaining demand. Norway's spectacular growth in this field has been the talk of the industry. But it's significant that this has been as much a marketing triumph as a technological one. Norway, as long ago as 1970, coordinated aquaculture marketing through a central organization. Its industry sells hard and continuously throughout the world. We're going to have to sell hard and continuously too, if we are going to succeed.

In closing, let me address the most basic need of the Canadian industry. In a professional study of the problems of fisheries management made a few years ago, it was noted that a lack of coordinating and focussing institutions can be a disabling condition for an industry. It impedes strategic planning. It lowers the quality of decision-making by individual companies and by the industry collectively.

An aquaculturist has much in common with a farmer. One similarity is that he or she is apt to be a highly individualistic and self-reliant person. But aquaculturists are learning as farmers did that some needs must be addressed collectively. Without organization you lack focus, you lack a long-range perception of opportunities, you even lack the ability to talk systematically to each other. In the competition for funding, for resource use, for attention to your concerns, the unorganized industry is likely to get walked all over.

Throughout Canada, aquaculturists have taken the first steps toward organization. Your provincial associations match the needs of the earlier stage of development. But your current needs and your expectations require a national presence now. The Ontario Trout Farmers Association has helped the whole industry by campaigning for such a coalition. The Department of Fisheries and Oceans and the Science Council of Canada have performed a useful service by calling this conference and providing an unprecedented opportunity to make plans for organization. It will, I hope, need to be renamed for the record. Not just the National Aquaculture Conference, but the *First* National Aquaculture Conference.

The choice really is ours. This gathering can turn out to be routine — on occasion when fish farmers and others involved in aquaculture exchanged progress reports and shop talk and then went their separate ways. Or it can be a milestone in the history of the industry. If this Conference can lay the groundwork for an active national aquacultural association, it will have served a practical and historic purpose. That will be the first step in *Getting our Act Together*. Then we can hopefully adopt *Pisces Pecuniaris* as our mascot.

Thank you.

AQUACULTURE IN ATLANTIC CANADA

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ABSTRACT

Aiken, D. E. 1984. Aquaculture in Atlantic Canada, p. 6–15. *In* G. I. Pritchard [ed.] Proceedings of the National Aquaculture Conference — strategies for aquaculture development in Canada. Can. Spec. Publ. Fish. Aquat. Sci. 75.

Atlantic Canada has the greatest diversity of aquaculture activities of any region in the country. Seven species are currently in some form of commercial culture in the area: Atlantic salmon, rainbow trout, brook trout, bluefin tuna, American lobster, American oyster, and blue mussel. Six other species are in various stages of research or development as culture prospects.

The most spectacular species in terms of increased value from aquaculture production has been Atlantic salmon. From 6 tonnes (t) valued at $60 thousand in 1979, salmon production from sea cages increased to 147 t worth nearly $1.8 million in 1982. Commercial production from sea cages has been concentrated in the Bay of Fundy where water exchange and winter temperature are suitable, but other areas are being evaluated. Rainbow trout also grow well in sea cages, and can be utilized by salmon growers as a cash crop.

Although the American oyster is a major seafood product in the region, most so-called "culture" production is actually the transfer of wild oysters to leases where quality is improved prior to sale. Various estimates indicate the current production of approximately 612 t could be doubled if pollution were controlled and efficient husbandry practices adopted. Culture of the American oyster is limited to areas with warm summer temperatures, specifically the Gulf of St. Lawrence and Bras d'Or Lakes, but the European oyster is more tolerant of cold water and attemps are underway to establish commercial culture of this so-called "Belon" oyster along the outer coast of Nova Scotia.

Blue mussel is an attractive complement to oyster culture since it grows well in areas too extreme for the American oyster. The poor market prospects that once impeded development of the mussel culture industry appear to have changed, and many now consider this species to have as much promise as any in the region.

Bluefin tuna and American lobster are both subject to Catch–Hold–Sell or "feedlot" culture in the region, being captured from the wild and fattened for later sale. The potential of bluefin tuna culture has not been realized because of strict quotas on capture of the species, but the prospects for a steady increase in return from lobsters handled this way are excellent as facilities and technology improve.

The ultimate success of the aquaculture industry in the region will depend on how well current problems are addressed. Some problems are species specific (seed supply, marketing, feed technology), but others have general impact. Property rights, lease control, and protection from pollution are in this category. Finally, there is a need for financial and investment incentives and extension services for new aquaculture ventures. These have been important in the development of the agriculture and forestry industries and will be no less so in the development of an aquaculture industry in Atlantic Canada.

INTRODUCTION

Aquaculture practices in some parts of the world can be traced back almost 12 000 years, nearly as far as agriculture. The Pharaohs of Egypt apparently cultured tilapia and the Romans grew oysters and fattened fish in ponds. Ancient writings suggest that fish were being raised in ponds in China and India more than 2 500 years ago, and pond construction methods for the farming of milkfish and mullet were brought to the islands of Hawaii by the Polynesians nearly 1 000 years ago (Borgese 1980).

In contrast, the concept of growing aquatic organisms as food for humans is relatively new in North America. Historically, North American aquaculture has been for resource enhancement purposes. There have been several reasons for this: productive commercial fisheries, unlimited resources from the freshwater and marine environment, different food preferences, and relatively inexpensive terrestrial sources of animal protein. These factors have been changing in recent years, and interest in and support for aquaculture has increased as a result.

In Canada, aquaculture began in the 1800s with the construction of salmonid hatcheries in the Maritimes (MacCrimmon et al. 1974). Initially only fry were released, but with improved husbandry techniques there has been a trend toward the rearing and stocking of larger fish. By 1970, when production from 14 federal hatcheries was almost 100 000 kg, 54% of salmon and 17% of trout were released as smolt and 15-cm fish, respectively (Ritter and Carey 1980). Although the current annual production of 500 000 smolt is intended primarily for resource enhancement, limited numbers have been made available to private growers and this had been directly responsible for the success of the salmon cage-culture industry in the Maritimes.

Atlantic Canada now has the greatest diversity of aquaculture products of any region in Canada. The various types of commercial marine and freshwater aquaculture encompass seven species: Atlantic salmon, rainbow trout, brook trout, bluefin tuna, American lobster, American oyster, and blue mussel. In addition, quahog, pink salmon, bay scallop, European oyster, eel, and Irish moss have been considered to have culture potential (Table 1).

TABLE 1. Commercial aquaculture production, pilot scale projects, and feasibility research in Atlantic Canada by province and species in 1982.

Province	Species	Growers (*n*)	Production (t)	Culture methods	Status C	Status P	Status R
N.B.	At salmon	5	147	SW cage	X		X
	Rb trout	4	15	Raceway, Pond, Cage	X		
	Bk trout	2	5	Raceway, Pond, Cage	X	X	
	Am oyster	50–100	85**	Wild seed; Bottom cult.	X	X	
	Bl mussel	2	—	Wild seed; longline		X	
	Quahog	1	—	Hatchery?			X
N.S.	At salmon	—	—	Genetics research			X
	Rb trout	3	136	SW cage (some fish-out)	X		
	Bk trout	—	—	Fish-out ponds	(X)		
	Bf tuna	1	59	Catch–Hold–Sell (nets)	X		
	Am oyster	?	77*	Bottom (Buy–Hold–Sell)	X		
	Eu oyster	7	Test mkt	Tray; Lantern net		X	X
	Bl mussel	12	?	Wild seed; Longline	X		
	Quahog	—	—	Hatchery for resource			X
P.E.I.	Rb trout	8	15	SW cage rearing	X		
	Bk trout	1	?	SW cage rearing	?		
	Am oyster	?	450*	Catch–Hold–Sell	X		
	Bl mussel	18	?	Wild seed; longline	X		
	Am lobster	1	?	Catch–Molt–Sell and		X	
		1	0	Complete grow-out			X
	By scallop	1	—	Out of quarantine			X
Nfld.	Rb trout	1	30	?	X		
	Bl mussel	1	0	Longline; Net-array	(X)		X
	Se scallop	2	0.25***	Wild seed; Pearl net then lantern tray	(X)		X

Am-American; Bk-Brook; Bf-Bluefin; Bl-Blue; By-Bay; C-commercial; Eu-European; P-pilot-scale project; R-research; Rb-Rainbow; Se-sea; SW-sea water; *calculated as 50% of total landings; **calculated as 25% of total landings; ***meat weight only (plus additional 16 000 seed scallops sold for resource enhancement); (X) marginal or quasi-commercial production; ? specific information not available.

Virtually all of this development has occurred in the last decade. In the 1960s, aquaculture production in Atlantic Canada was limited to some private oyster production and one small trout farm at Comeauville, Nova Scotia. In 1970, Seapool Fisheries launched a multimillion dollar salmonid culture operation near Clam Bay, Nova Scotia, an event heralded as the dawn of aquaculture development in the Atlantic region. The industry suffered a severe setback when Seapool Fisheries slipped into bankruptcy only 2 yr later, but by 1980 more than three dozen salmonid aquaculture ventures had become established and annual production of vertebrate and invertebrate freshwater and marine species approached 1 200 t. In spite of this dramatic growth, food production from the Atlantic aquaculture industry is still insignificant in comparison to the traditional fishery, an industry that employs 125 000 people and has annual sales approaching $2 billion.

"Aquaculture" is a term with many definitions. "Husbandry of aquatic plants and animals" is generally acceptable, but many insist the scope should include only those activities that produce food for direct human consumption. On the other extreme are those who insist that aquaculture also includes production to enhance wild stocks for commercial purposes, the production of bait, the propogation of ornamental fish and plants, the culture of molluscs for pearls, the cultivation of unicellular algae for animal feeds, and so on. Without prejudice to any definition of aquaculture, the material in this paper is restricted to those aquaculture practices that produce organisms as food for human consumption, although not necessarily directly. Baitfish, pearl molluscs and ornamentals for the aquarium trade are therefore excluded. To the extent it is possible I have also excluded production intended exclusively for stock enhancement.

The salmonids are a group that illustrates how difficult it is to draw a clear distinction between aquaculture for human food and aquaculture for resource enhancement. Salmon released from a government hatchery to augment stocks are clearly intended to enhance the resource. Salmon released from a private hatchery for sea ranching are clearly intended for human food, yet many of these disappear into the capture and sport fisheries to become part of the resource and thereby enhance that resource. Both groups of salmon are produced as food for human consumption, one by a private interest for its own profit, the other by public interest for the profit of others. Profit is therefore the distinguishing feature, not food. And the situation is no less complex in the freshwater environment. Trout from public hatcheries stocked in public ponds for sport fishing by fee-paying licensees are only marginally different from those purchased from private hatcheries and stocked in private ponds for pay-as-you-catch sportsmen. Those stocked in a pothole to be harvested for personal use may as easily be bartered to a neighbor or sold outright from the bank of the pond. The variations are many and the distinctions probably meaningless.

One other aspect of culture deserves mention because it is even more difficult to deal with in decisive fashion, especially in Atlantic Canada. In its purest (and rarest) form, aquaculture involves the breeding, rearing, and marketing of aquatic organisms. However, for some of our most productive cultured species, wild seed are harvested for growout. For others the wild harvest occurs at an advanced life stage and growers practice a "Catch–Hold–Sell" form of culture. For example, a significant proportion of the oyster production on Prince Edward Island involves oysters purchased from fisherman in spring, transferred to bottom culture on private oyster leases, and sold in the fall. This seems to be generally regarded as "culture," but if it is, then the spring capture, summer internment, and autumn sale of bluefin tuna in St. Margarets Bay is Catch–Hold–Sell culture (also called "feedlot culture"). Having accepted this (and most people do), we must then decide what to do about that segment of the lobster impoundment industry that buys in summer–fall, holds through autumn in tidal impoundments or land-based facilities, and markets in winter when the supply is low and the price high. This is an enterprise that was carried on long before aquaculture became a household word, and as a result it is not included as part of the "new" technology. But these lobsters are captured, impounded and fed as are tuna, and they are exposed to more husbandry than an oyster on the bottom of a lease in Prince Edward Island. Either impounded oysters, mussels and tuna should be excluded, or impounded lobsters should be included. In this paper I have bowed to this logic and included the Catch–Hold–Sell aspect of the traditional lobster industry in the total value of "aquaculture" practices in the Atlantic region.

REGIONAL PROFILE

The population of Atlantic Canada is best described as rural maritime, heavily dependent on the seasonal occupations of forestry, farming, and fishing, and plagued by unemployment. Twenty five percent of the total population of the Atlantic provinces live in more than 1 300 small fishing villages where alternative employment is limited. If the recommendations of the Task Force on the Atlantic Fishery are implemented, the number of men from these villages who fish for a living will be further reduced and the number seeking alternative employment correspondingly increased. Aquaculture is an industry that blends with the social organization of rural communities, employs local expertise, and provides badly needed alternative employment.

The climate, geology, and hydrography of Atlantic Canada vary considerably from one locality to another, much more so than on the west coast of Canada, and for those reasons aquaculture opportunities also vary from place to place. Those portions of New Brunswick and Nova Scotia that face Passamaquoddy Bay and the Bay of Fundy (Fig. 1) experience open water year round, tidal amplitudes in excess of 8 m, strong currents and water temperatures that vary from around 0°C in February to approximately 13°C in late summer. Such conditions are ideal for lobster feedlot culture and acceptable for salmon cage culture, but because of problems with paralytic shellfish poisoning the area is considered unsuitable for the culture of mussels.

Except for a more moderate tidal flux (2–3 m), the presence of winter ice in protected areas, and the absence of paralytic shellfish poisoning, conditions are similar along the

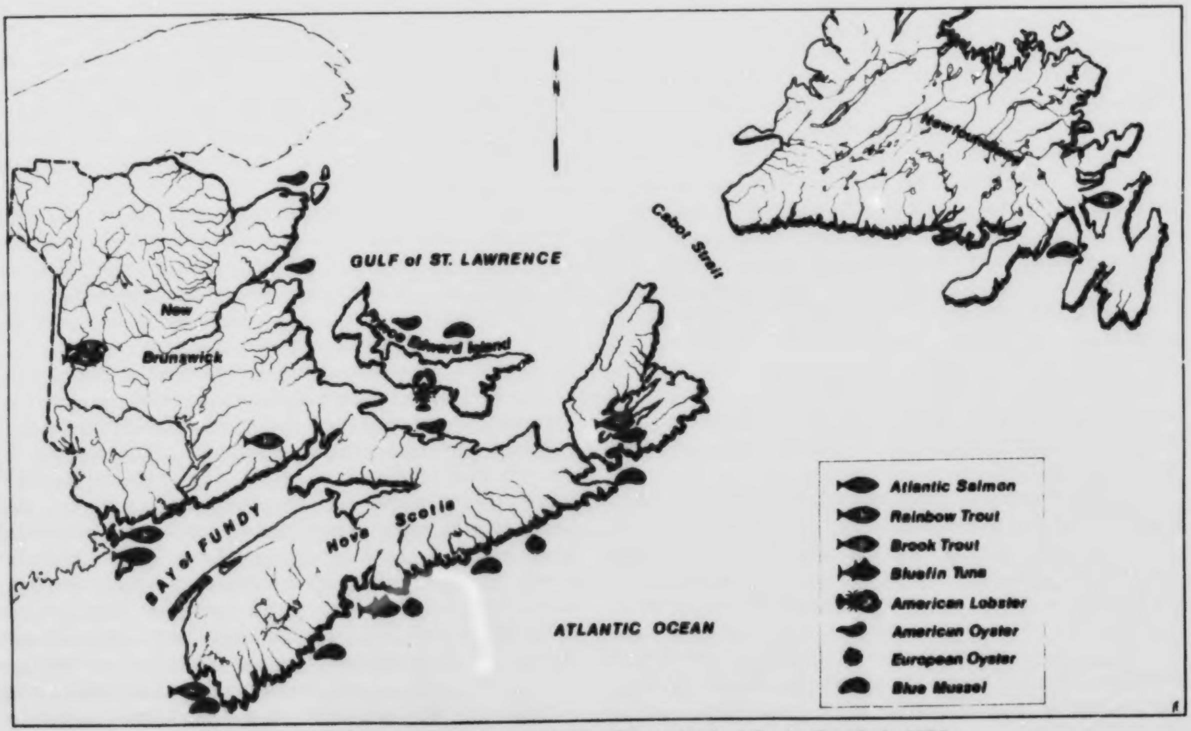

FIG. 1. Distribution of aquaculture activities by species in Atlantic Canada in 1982.

outer coast of Nova Scotia. The coastline is rocky, the waters are productive, and sheltered coves and bays are abundant. From Clark's Harbour at the southern tip of Nova Scotia the outer coast runs a convoluted 550 km northeast to Glace Bay, Cape Breton Island. Facing the open sea and the continental slope, the coastline is suitable for culture of mussel and European oyster and for some forms of lobster and salmonid husbandry.

West from Cape Breton Island is the Gulf of St. Lawrence, a sandy, relatively shallow sea surrounded on three sides by land (Fig. 1). Tidal amplitude in the southern Gulf is barely more than a metre and currents are minimal. Winter ice is common, but summer water temperatures are the highest north of Massachusetts, rising well above 20°C in some areas. It is this elevated summer temperature that makes the region attractive for culture of the American oyster.

Newfoundland lies across the Laurentian Channel to the northeast. The rocky, exposed, often precipitous coastline of the south shore and Avalon Peninsula is not very different from the southeast shore of Nova Scotia, but the latitude is considerably higher and becomes rapidly more so along the eastern and western coastlines of the province. Mussels, sea scallops, and salmonids appear to be reasonable culture prospects for southern Newfoundland.

Two other areas deserve mention. The Bras d'Or Lakes system is a large (1 000 km^2) stratified body of water on Cape Breton Island. The lakes are embraced by arms of land that leave a narrow access to the sea and limit the intrusion of salt water. This, combined with a significant freshwater drainage area, results in a stratified system consisting of a deep saline layer overlain by a 6–15 m surface layer of fresh or brackish water (Krauel 1975). Similar conditions are found in Kennebecasis Bay, northwest of Saint John, New Brunswick. The entire bay, some 58 km^2, has a deep layer of saline water of 19–22 ppt overlain by approximately 10 m of fresh water (0–10 ppt). As in the Bras d'Or, the surface water freezes in winter, but the deep saline water remains warmer (above 4°C in Kennebacasis Bay). These unique areas offer challenging opportunities for innovative aquaculture in Atlantic Canada.

The freshwater situation is somewhat different. Abundant and reliable supplies for both ground and surface water are necessary for some phases of salmonid culture, and the status of such supplies in Newfoundland and Prince Edward Island is questionable. Nova Scotia and New Brunswick, on the other hand, appear to have adequate supplies of both ground and surface water for salmonid culture.

SPECIES CULTURED IN ATLANTIC CANADA

Seven of the eight species discussed in this section are the object of commercial husbandry somewhere in the Atlantic region. Because of the variety of conditions in the area, an organism marketed commercially in one area can be in pilot scale in a second and experimental in a third. The eighth species — the European oyster — is listed because it is under intensive culture in Nova Scotia and is considered to have commercial potential.

Atlantic Salmon

The developing cage-culture industry for Atlantic salmon (Fig. 2A) is an example of the benefits that can accrue from carefully planned research and development programs. In 1978, the Department of Fisheries and Oceans, the New Brunswick Department of Fisheries, and a private firm pooled their resources and expertise to determine the commercial feasibility of cage culture for Atlantic salmon in the Bay of Fundy (Sutterlin et al. 1981b). Salmon had previously been overwintered in the Bay (Baker 1975), but conditions in many localities were marginal and commercial interest had never developed. In the spring of 1978, 3 500 salmon smolt were transferred to sea cages off Deer Island, a site chosen for good water exchange, freedom from severe wave action, and temperatures that remained above the lower lethal for salmon. Eighteen months later, 6 t of salmon averaging 3.3 kg were harvested from those cages and sold for $7.70/kg dressed. The success of that feasibility study was such that by 1982 there were five salmon sea-cage operations in New Brunswick waters, with a combined estimated production of 147 t. In addition, four private hatcheries in southern New Brunswick were producing salmon smolt for the expanding cage-culture industry.

It has been estimated that a minimum production of 50 t is necessary for economic viability of salmon cage rearing. Such an operation could be run by two men starting with about 20 000 smolt, but other companies would have to be relied on for smolt, feed, and processing–marketing. According to J. M. Anderson (personal communication), a vertically integrated facility that produced eggs, formulated rations, and handled its own marketing would require a production of approximately 350 t annually for economic viability. After 18 months about 20% of cage-reared Atlantic salmon will normally reach the premium weight of 4.5–5.5 kg, a size suitable for smoking (Fig. 2B), and the other 80% will weigh about 3.5 kg, normally sold dressed at a lower price. Fresh salmon is the traditional product, and properly handled it has a shelf life of 8–10 days. Frozen salmon, a product that allows greater marketing flexibility, is becoming more acceptable to the consumer but the high lipid content limits frozen storage to less than 3 months. Thus with a structured production and harvest schedule and a mix of fresh and frozen product, it is possible to guarantee a supply of fresh or fresh-frozen cultured Atlantic salmon from late fall through the following May, the period during which supplies from the commercial fishery are either diminished or deteriorating. It is anticipated that the domestic market can absorb at least 500 t during this period (J. M. Anderson, personal communication).

The best area for commercial cage culture of Atlantic salmon appears to be the Bay of Fundy off New Brunswick. The southern tip of Nova Scotia from Yarmouth to Lockeport also has potential, but additional information is required on winter seawater temperatures. Three other locations in Atlantic Canada may support commercial operations: the Bras d'Or Lakes system on Cape Breton Island, Kennebecasis Bay in New Brunswick (Anderson 1982), and Bay d'Espoir, Newfoundland (Sutterlin 1980).

Other than winter seawater temperature, the most serious constraint on the developing salmon cage-culture industry is the severe shortage of smolt. The majority used in cage rearing are purchased from federal government hatcheries at close to $2 per smolt, and the supply falls short of demand. Private hatcheries are attempting to fill the need, but significant supplies will not be available until 1984–85 at the earliest.

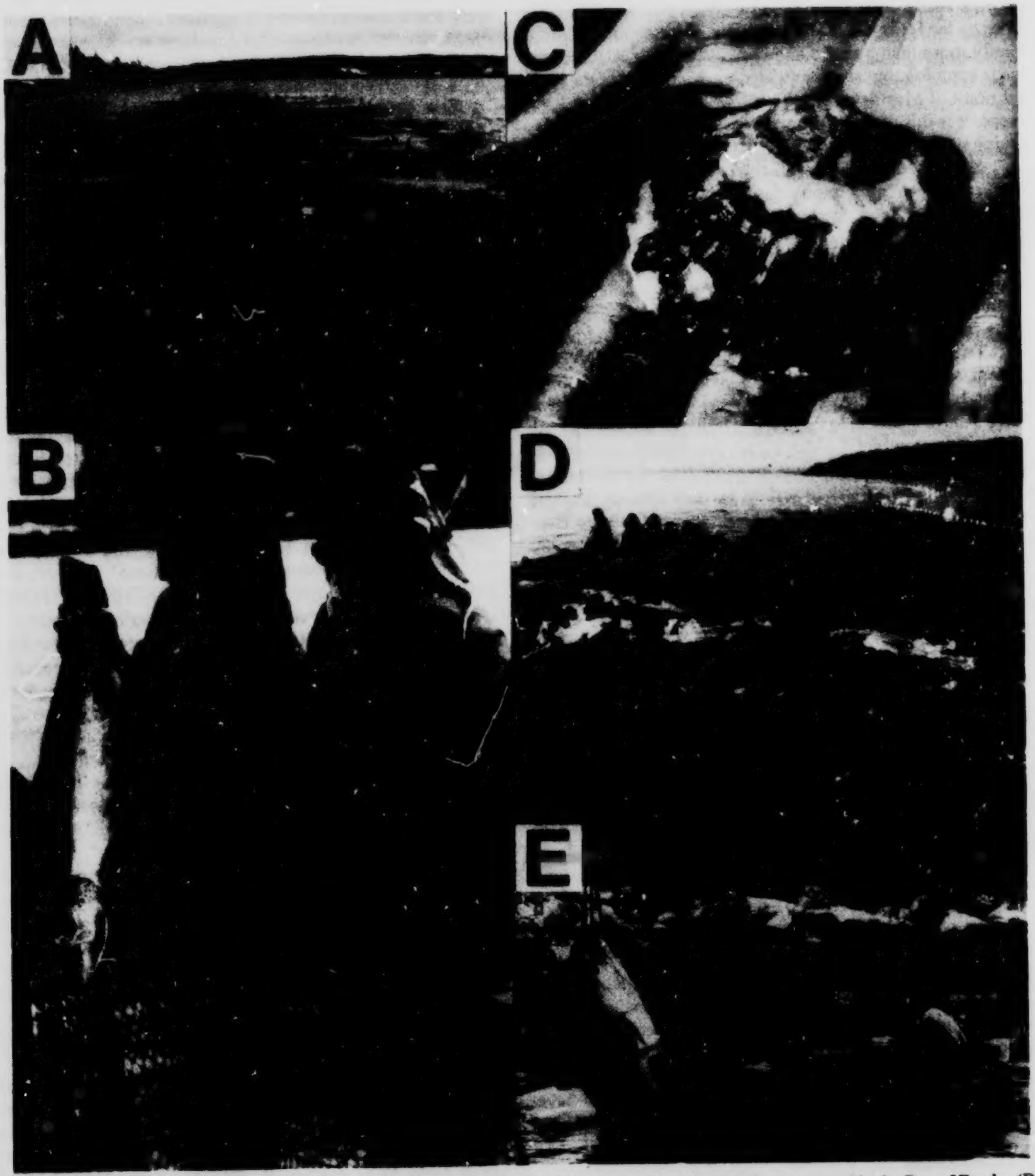

FIG. 2. Aspects of the aquaculture industry in Atlantic Canada in 1982. (A) net cages for Atlantic salmon moored in the Bay of Fundy, (B) 4–5 kg Atlantic salmon harvested from Bay of Fundy cages, (C) European (flat or "Belon") oyster grown along the Atlantic coast of Nova Scotia, and (D–E) harvest of bluefin tuna from net pens in St. Margarets Bay, Nova Scotia.

Two other factors are frequently cited by growers as impeding expansion of the industry: (a) Fisheries Act regulations that affect the importation and transportation of salmonids, and (b) the difficulty in obtaining financing. As Sutterlin (1980) pointed out, "Normal banking practices require that working capital be repaid in short term intervals such as 30, 60, or 90 days. . . the realities of producing salmon . . . require large capital and operational expenses three years before revenues begin to accrue."

Trout

Only two trout species are reared commercially in the region: rainbow (*Salmo gairdneri*), and brook or speckled (*Salvelinus fontinalis*). Rainbow is preferred by 80% of the growers.

Trout farming remains a popular aquaculture venture, especially for small operators. The technology is well known, formulated rations can be obtained commercially, and seed stock is available from several sources. Under good growing conditions, eggs can be turned into a cash crop in 12–18 months.

Rainbow is the principal salmonid in Prince Edward Island, where eight growers produced about 15 t in 1982. In Newfoundland, only one grower was active in 1982. Production from that operation was nearly 30 t, 80% of which was sold locally. Most of the regional trout production was in New Brunswick and Nova Scotia. There were only three growers in Nova Scotia last year but their combined production was about 136 t of rainbow trout. Rainbow and brook trout were also stocked in private fish-out ponds in the province. Trout production from six sites in New Brunswick was about 20 t, of which 14.7 t was rainbow. Of these totals approximately 5 t each of rainbow and brook trout were grown in raceways or ponds instead of sea cages.

The possibilities for expansion in trout culture look reasonable because of the unsatisfied market for steak-size fish. Trout raised for market have traditionally been the 140–225 g "pan-size" fish. However, trout weighing 1.8–3.6 kg are in demand and can be produced more quickly in sea cages than in freshwater facilities. They have the added advantage of being marketable any time after pan size is reached, a distinct plus for an operation squeezed for cash. Atlantic salmon, on the other hand, have little market appeal before they reach 3.5 kg at the end of their second summer.

Bluefin Tuna

In June, bluefin tuna (*Thunnus thynnus*) follow mackerel into the mackerel traps in St. Margarets Bay, west of Halifax, N.S., where they are captured and transferred to large impoundment nets anchored to the sea floor nearby in 30 m of water. From mid-June, when they are captured, until harvest in late October, the tuna are fed mackerel at the rate of 8–10% of body weight per day. During this 4-month holding period, they may gain 90 kg in weight (Fig. 2D,E). In 1974, 50 tuna were impounded in two enclosures. In 1976 there were nine impoundments holding 300 fish. In 1977 they expanded to 18 enclosures and 948 fish, employing 100 people and dressing 340 t tuna for air shipment to Japan. The following year a decline began: only 530 fish were captured for the 23 impoundments, and this slide culminated in a low of 116 tuna in 1982. The present quota on capture of bluefin for culture seriously limits the potential of this industry.

American Oyster

Summer seawater temperature determines the spawning success and survival of *Crassostrea virginica*, so culture is restricted to areas with a favorable temperature regime. In Atlantic Canada those areas are the southern Gulf of St. Lawrence and the Bras d'Or Lakes.

The status of the American oyster as a cultured species is not easily determined. In landed weight the oyster stands well ahead of all other cultured species in the region (Table 2), but since oyster production figures are not broken down into cultured versus fished, any value given as "aquaculture" production is an estimate. Full-scale culture starts with spat collection, takes 5–7 years for a marketable oyster, and currently contributes only a small proportion of the total commercial production. In Prince Edward Island, Catch–Hold–Sell is the principal culture method. Marketable oysters are purchased from fishermen in spring, transferred to leases, and marketed in autumn. Sometimes the holding period is as short as a month, as in the "transfer fishery" of New Brunswick. In Nova Scotia one grower buys his seed oysters, holds off-bottom in trays, and then markets. Oysters taken from the wild in autumn and marketed are clearly fishery products, but the other variations are not easily catergorized. MacCrimmon et al. (1974) estimated that less than 15% of the total oyster production comes from culture,

Table 2. Approximate production and value (thousands of dollars) of aquaculture products from Atlantic Canada between 1979 and 1982.

	1982		1981		1980		1979	
	t	$	t	$	t	$	t	$
Atlantic salmon	147	1788	28	277	3	20	6	60
Pink salmon	—	—	3	7	—	—	—	—
Rainbow trout	195	820	86	354	83	299	100	635
Brook trout	3	12	—	—	—	—	—	—
Bluefin tuna	59	268	34	148	30	127	95	391
American lobster[a]	210	1050	217	934	185	737	197	763
American oyster	612	747	700	1509	1103	1024	1038	941
Blue mussel	175	74	82	81	36	37	24	28
Total	1401	4760	1150	3309	1440	2244	1460	2818

Most values for 1979–81 are from I.C.E.S. Administrative Reports, Mariculture Committee. 1982 salmonid production figures from N.B. Department of Fisheries.

[a] Based on 1% of reported landings (Ottawa).

but the figure used in compiling I.C.E.S. Mariculture Committee Administrative Reports varies from 50 to 70% of reported landings. Further complicating this analysis is the acknowledged fact that many sales are neither reported nor recorded.

In Nova Scotia it has been estimated that the available bottom could produce 50 000 boxes (300–400 oysters per box), but production from the province has never exceeded 8 000 boxes. Some people feel the Nova Scotia oyster production, about 77 t in 1982, could be expanded considerably through careful husbandry. Prince Edward Island produced 900 t of oyster in 1982, a decrease of more than 300 t from 1981. The 50% estimate suggests 450 t of this was attributable to some form of culture. In New Brunswick, 1982 oyster production was 338 t (worth some $343,000 to the province), up 38 t from 1981. However, provincial officials estimate that only 25% of this, or 85 t, was from actual culture. These estimates indicate that culture production accounted for approximately 612 t of Atlantic oyster worth almost three-quarters of a million dollars to Atlantic Canada in 1982.

Blue Mussel

Like salmon cage culture, mussel culture is a regional success story. Not many years ago *Mytilus edulis* was a questionable culture prospect in Atlantic Canada (Jamieson et al. 1975). Abundant, fast-growing, easily cultured, tasty and nutritious, the blue mussel had only one flaw — there was no market for the product. Aggressive marketing seems to have turned that around to the point that mussels are now one of the region's most promising species.

The "mussel beach" of Atlantic Canada seems to be Nova Scotia, where some growers have more than 8 000 collectors out. Exact production is not known, but there are a dozen growers from Chedabucto Bay down to Argyle. Prince Edward Island is close behind with 18 growers, 4–5 of which run large operations. Total 1982 production can only be estimated since accurate production figures are impossible to obtain. Various estimates place the 1982 regional production close to 175 t.

Mussel culture is just starting in New Brunswick. There are two pilot scale operations in the northeast part of the province, and one of these has 12 000 collectors in place. Unfortunately, the persistence of paralytic shellfish poisoning in the Bay of Fundy and Passamaquoddy regions has eliminated many kilometres of excellent coastline from production. Efforts to date in Newfoundland have been limited to two small operations, neither of which expects a reasonable harvest before 1984. However, Sutterlin et at. (1981a) concluded there was considerable potential for mussel culture in Newfoundland waters.

American Lobster

Because of its high value, insatiable market demand, and uncertain future as a fisheries product, the American lobster (***Homarus americanus***) has been the object of culture research in Canada and the United States for more than a decade (Van Olst et al. 1980). In Canada preliminary work on integrated lobster culture systems began about 7 years ago and was recently carried to the pilot scale level in Atlantic Canada with financial support from the federal government.

There are three types of lobster culture: (a) Full-scale (egg to market), (b) Catch–Molt–Sell (growing the wild animal to a larger and more valuable size), and (c) Catch–Hold–Sell (holding to improve condition and sell at higher price). The first two are still experimental but Catch–Hold–Sell includes a range of activities from the short-term storage described by McLeese and Wilder (1964) to holding individually for months in land based facilities. Lately there has been increasing interest in holding to improve the quality, percent meat yield, and economic return on the livestock. This is the same type of "feedlot" culture practiced on tuna and oysters. In 1982, the landed value of the lobster fishery was $105 million. If only 1% of the landed value passes through extended holding with some measure of husbandry before reaching the consumer, lobster would still rank second only to Atlantic salmon as an aquaculture product in Atlantic Canada.

European Oyster

The European or "flat" oyster (*Ostrea edulis*) now cultured in Atlantic Canada (Fig. 2C) came from Holland via Maine. *Ostrea* can grow and reproduce at lower temperatures than *Crassostrea*, and it broods its larvae to the shelled stage before discharging them. Many consider the European oyster an ideal candidate for culture in the oceanic areas of Atlantic Canada where water temperature is too low for the culture of the American oyster.

Although two attempts to establish the species in Newfoundland waters failed (1971–72), more than a half-dozen growers have established viable stocks along the east coast of Nova Scotia. Limited seed supply has been a constraint, and the growth rate (3–4 years to market size), although faster than the American oyster, is still longer than ideal. The primary market for these so-called Belon oysters from Nova Scotia is the eastern United States, where test marketing has revealed good consumer response. If the seed supply problem can be overcome and the growth rate enhanced through genetic selection or ingenious husbandry, this species has a reasonable chance for commercial viability.

Potential for Culture

Five additional species have characteristics that make them attractive for culture in the region, but major problems exist and economic viability in the near future seems unlikely.

Sea Scallop

Placopecten magellanicus has been under evaluation as a culture species in Newfoundland since 1971, when work was initiated by the Newfoundland Department of Fisheries. The federal Department of Fisheries and Oceans became involved in 1976.

Attempts at hatchery production of spat have been unsuccessful, so spat are collected from the wild with monofilament gill netting or opaque polyethylene film in an enclosure on the sea bottom. The following autumn, spat are removed and transferred to pearl nets where they remain for 6–8 months. They are then transferred to the sea bottom or to suspended accordian trays.

Economic studies indicate tray culture is too labor intensive to be profitible, but bottom culture might yeild an acceptable return on investment. In controlled tests to evaluate product quality, cultured *Placopecten* were judged different from their wild counterparts in both appearance and overall acceptability, but no preference was established for either the wild or the cultured scallop.

Sea scallop culture was attempted commercially at two sites in Newfoundland. One grower has had serious problems locating good areas for spat collection but the other marketed 10 000 3-year old scallops (7 000 to St. Pierre for an enhancement project, 3 000 on a retail basis locally). In addition, 16 000 seed scallops were sold to St. Pierre.

Bay Scallop

The Atlantic bay scallop (*Argopecten irradians*), obtained from Milford Connecticut several years ago, was quarantined at Ellerslie, P.E.I. through the F4 generation. The species is now available for culture work but the province has no immediate plans to carry the investigation further.

Quahog

Both New Brunswick and Prince Edward Island have been looking at the culture possibilities of *Mercenaria mercenaria*. Prince Edward Island has discontinued its program and it appears that New Brunswick, which has been involved in a pilot scale study for 3 years, will do likewise. Neither feels there is any prospect of economic viability in spite of dramatic price increases in recent years.

American Eel

Roughly 10 years ago eel farms were established at Pokemouche and Burnt Church in northeastern New Brunswick with the objective of raising the elver of *Anguilla rostrata* to 200 g for live export to Japan. Severe losses due to low winter temperature and instability in the Japanese market dealt a fatal blow to those plans. Neish (1976) concluded that eel culture had no real potential in New Brunswick, and that conclusion still appears valid.

Irish Moss

In Atlantic Canada, Irish moss (*Chondrus crispus*) is the most likely seaweed for culture. Large natural beds are found off western Prince Edward Island and southwest Nova Scotia, and these two areas supply roughly 70% of the 30 000 t mean annual harvest from the area. *Chondrus* is a good source of carageenan, and high quality carageenan can command more than $15/kg. Private firms funded with government money began trying to develop and culture a superior grade of *Chondrus* about 10 years ago, but commercial production has not yet been realized.

PROSPECTS AND PROBLEMS

The value of aquaculture production in Atlantic Canada has increased significantly over the last 3 years (Fig. 3) and the prospects for continued growth appear reasonably good. Salmon, trout, oyster, mussel, and lobster are all amenable to husbandry, and all except the mussel enjoy traditional markets. Consumer acceptance of the blue mussel has improved considerably in recent years, and with responsible marketing the demand for that species should continue to grow.

Of the seven species that were subjected to some form of husbandry, the most valuable in 1982 was Atlantic salmon, followed by the American lobster, rainbow trout, and American oyster (Fig. 4). Of the remaining three, only the blue mussel shows real promise of expanding its share of the market over the next 5 years.

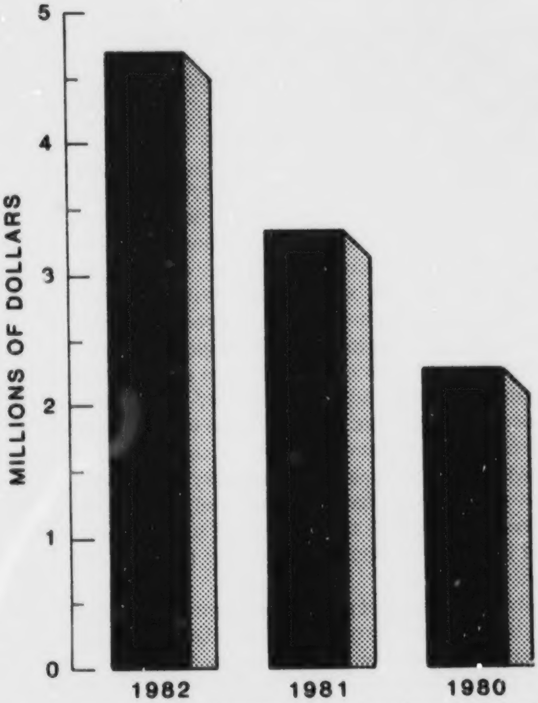

Fig. 3. Trend in value of aquaculture products from Atlantic Canada 1980–82.

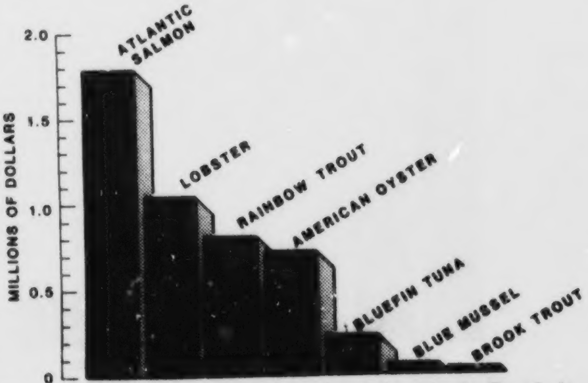

Fig. 4. Relative value of species cultured in Atlantic Canada in 1982.

Among the salmonids, which as a group were worth more than $2.6 million in 1982, the most remarkable change occurred in Atlantic salmon. In 1980, the value of this species as an aquaculture product was insignificant compared to trout, but by 1982 this relationship had reversed (Fig. 5) and there is every indication Atlantic salmon will continue to strengthen.

The scaling up of aquaculture is a complex business, and the chicken and egg syndrome is common: production cannot continue unless a market exists, but the market will not exist unless production can be guaranteed. In the crucial early years of development of any species, such a guarantee is difficult to service. Nor is the problem restricted to the top end of the system. Few growers want to start with a vertically integrated facility, preferring instead to purchase seed and feed from others. However, the producers of seed and feed also require a guaranteed market before they can scale up their production. If they don't produce, the growers can't grow, but if the growers don't grow, there is no market for the seed stock. The rapid development of salmon cage rearing in Atlantic Canada is due in large part to government intervention in this cycle. Federal hatcheries were already producing fish for resource enhancement and thus didn't need a guaranteed market. The production of a few additional smolt to nurture the growers until they could produce their own was a minor but crucial effort. Without it, the salmon cage industry would not have developed as it did.

A different situation faces those growers attempting to develop the European oyster. There is no federal hatchery program producing large amounts of seed for resource enhancement, and there is no wild seed to be harvested. The growers of *Ostrea* therefore have no convenient source of seed with which to expand their industry. This is a situation where a government hatchery could help by producing the seed necessary to get the industry to a point where there would be sufficient demand to support the development of private hatcheries.

Oyster and mussel growers are protected to some extent from the seed stock problem by abundant wild seed which can be collected and transferred to leases for grow-out. Being efficient filter feeders these species also snare their own food and thereby spare their growers the nuisance of either preparing or purchasing formulated rations. This is a luxury not enjoyed by salmonid growers, but the price the shellfish growers pay is lack of control over stock. They are at the mercy of the wild gene pool, which the salmonid growers are not, and their opportunity to breed in and stabilize desirable characters is thereby diminished.

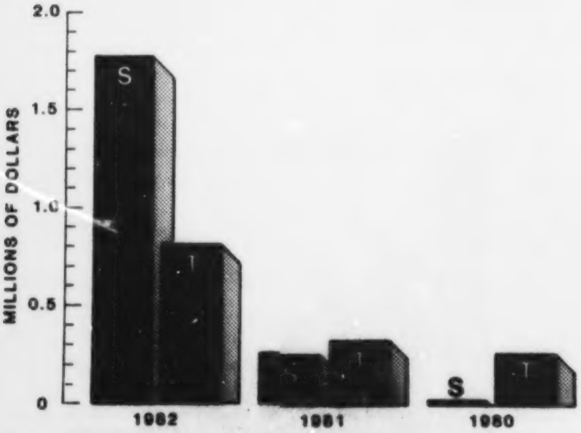

FIG. 5. Trend in relative value of trout and Atlantic salmon cultured in Atlantic Canada from 1980 through 1983.

Aquaculturists in the region face many of the same problems encountered (and largely overcome) by agriculturists. These fall into five broad categories: regulatory, property, marketing, financing, and extension. Salmonid growers in particular complain about regulations under the Fisheries Act that restrict the movement of their aquaculture products, regulations that do not apply in similar fashion to the movement of live lobster, for example. Salmonid growers maintaining sea cages and shellfish growers with nets or trays suspended in the water column must also contend with uncertainties concerning statutory rights over the product they are culturing (Wildsmith 1982).

Marketing can also be a serious problem for aquaculturists. A small grower serving a local area can usually handle his own marketing, but as the industry scales up the problems of competition, supply, price, quality, and outlet become more acute, requiring more time than the individual grower can afford to devote. There are several standard solutions — grower's associations, cooperatives, marketing boards, centralized shipping plants. All are variations on the principle of centralized marketing to take the burden off the small growers.

Financing and extension services have made an important contribution to the development of agriculture and forestry, and they are equally important to the growth and well-being of aquaculture. Unfortunately, they are not as readily available to aquaculturists. The financial community has tended to view aquaculture as a high-risk enterprise, partly because of its association with fisheries. Aquaculturists need the same types of financing, investment, and tax incentives that agriculturists enjoy. They also need access to the same types of extension services that are taken for granted in agriculture and forestry, services that provide research support on problems, advice and assistance in the design and construction of facilities, and assistance in the diagnosis and treatment of disease. In the Atlantic region the federal Department of Fisheries and Oceans maintains a Fish Health Unit at Halifax and attempts to provide diagnostic services to the industry, but this one unit cannot provide adequate service to aquaculturists growing a half-dozen different species throughout the Atlantic region. Provincial fisheries departments in the region attempt to provide advice and financial assistance to prospective growers, but the quality and depth of this service is variable. In the opinion of many regional aquaculturists, these types of services will have to be expanded considerably if the industry is to reach its full potential in Atlantic Canada.

ACKNOWLEDGEMENTS

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SURVEY OF AQUACULTURE PRACTICES IN QUEBEC

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ABSTRACT

BOULANGER, Y., AND L. E. HANSEN. 1984. Survey of aquacultural practices in Quebec, p. 16–24. *In* G. I. Pritchard [ed.] Proceedings of the National Aquaculture Conference — strategies for aquaculture development in Canada. Can. Spec. Publ. Fish. Aquat. Sci. 75.

The only form of commercial fish farming in Quebec is salmoniculture. The main agencies controlling fish culture are: the Ministère de l'Agriculture, des Pêcheries et de l'Alimentation (agriculture, fisheries, and food); the Ministère du Loisir, de la Chasse et de la Pêche (recreation, fish, and game); the Ministère de l'Environnement (environment), the Syndicat des pisciculteurs du Québec, and the Coopérative québecoise des pisciculteurs (fish breeders' associations).

In 1981, sales of rainbow and brook trout (99% of production) came to 348 570 kilograms and generated revenues of $3,037,302 for private fish breeders.

Currently, more than 417 commercial permits have been issued for the breeding of Salmonidae. This industry has benefited from capital investments of about $5 million since 1976. About half, i.e. $2,500,000 is from the private sector and the rest is from the Ministère de l'Agriculture, des Pêcheries et de l'Alimentation, in the form of loans and grants.

At the present time, between 100 and 150 persons/year are directly involved in the production of trout in Quebec.

The Ministère du Loisir, de la Chasse et de la Pêche operates seven fish hatcheries, which produce rainbow, brook, brown, and lake trout, landlocked salmon, maskinonge, and salmon for development programs in public water lots.

Trout production techniques in Quebec are described, with a list of the problems encountered with each.

The most common and widespread diseases are *Saprolegnia*, *Aeromonas hydrophilia*, and myxobacteria, but infectious necrosis of the pancreas and furunculosis are also present in Quebec, as are a few cases of kidney disease.

INTRODUCTION

Since Confederation, fish breeding in Quebec by the government sector has been limited to sport species, primarily Salmonidae. Commercial salmoniculture only started in the early 1940s. It is the only form of private fish farming in Quebec. Hansen et al. (1980), MacCrimmon et al. (1974), as well as Legendre et al. (1980) give a good historical overview of aquaculture in Quebec.

Fish breeding activities come under the jurisdiction of or involve three Quebec government departments (Wildsmith 1982):

— The Ministère du Loisir, de la Chasse et de la Pêche (MLCP) (Recreation, Fish and Game) controls the issuance of operating, transportation, and planting permits.

— The Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec (MAPAQ) (Agriculture, Fisheries and Food) is responsible for the inspection of food products and provides technical and financial resources to fish breeders.

— The Ministère de l'Environnement du Québec (MEQ) (Environment) ensures the protection of the environment during the construction and operation of fish breeding ventures.

[Translation]

Two fish breeders' associations play equally important roles in the piscicultural sector in Quebec.

— Le Syndicat des pisciculteurs:

All fish breeders are compulsory members of this agency under the 1981 marketing plan. Currently, its main role is that of lobbyist with the government to protect the breeders' interests (legalization of brook trout, grant policy, technical assistance); however, the marketing plan allows the agency to take on a more important role if the members so decide.

— La Coopérative québécoise des pisciculteurs:

Founded in 1975, it makes group purchases of equipment and trout meal. It has 80 members.

THE PRODUCTION OF SALMONIDAE

The data (Tables, etc.) on fish farm production in Quebec were gathered from the annual reports of the MLCP Aquaculture service. This service establishes its production estimates from transactions and the annual inventories that breeders must provide to obtain their operating permits. A study using other sources (Hansen et al. 1980) did not note any significant differences between its data and that of the MLCP.

The annual sale of Salmonidae from 1977 to 1981 (most recent year) is described in Tables 1, 2, and 3. Each table totals the number of brook and rainbow trout in a given

TABLE 1. Brook trout and rainbow trout fry sold annually from 1977 to 1981, according to market.

Type of market	1977		1978		1979		1980		1981	
	Brook trout	Rainbow trout	Brook trout	Rainbow trout	Brook trout	Rainbow trout	Brook trout	Rainbow trout	Brook trout	Rainbow trout
Sales for plantings	1 461 400	336 150	1 510 040	22 800	1 021 970	270 925	382 919	456 798	2 945 703	Insufficient data
Sales for breeding purposes between commercial fish breeders	1 581 300	153 000	711 600	591 000	2 417 800	650 000	1 160 425	186 000	943 460	576 500
Total	3 402 700	489 150	2 221 640	613 800	2 439 770	920 925	1 543 344	642 798	3 889 163	576 500

SOURCE: Annual reports, Pisciculture service of the Ministère du Loisir, de la Chasse et de la Pêche.

TABLE 2. Brook trout and rainbow trout fingerlings sold annually from 1977 to 1981, according to market.

Type of market	1977		1978		1979		1980		1981	
	Brook trout	Rainbow trout	Brook trout	Rainbow trout	Brook trout	Rainbow trout	Brook trout	Rainbow trout	Brook trout	Rainbow trout
Sales for plantings	1 522 250	239 715	1 474 448	102 870	1 433 892	193 235	1 691 969	90 977	1 097 286	222 470
Sales for breeding purposes between commercial fish breeders	166 300	115 000	426 721	86 200	344 580	100 800	899 954	491 057	672 920	194 920
Total	1 688 550	354 715	1 901 169	189 070	1 778 472	294 035	2 591 923	582 034	1 770 206	417 390

SOURCE: Annual reports, Pisciculture service of the Ministère du Loisir, de la Chasse et de la Pêche.

TABLE 3. Brook trout and rainbow trout over a year old, annual sales from 1977 to 1981, according to market.

Type of market	1977		1978		1979		1980		1981	
	Brook trout	Rainbow trout	Brook trout	Rainbow trout	Brook trout	Rainbow trout	Brook trout	Rainbow trout	Brook trout	Rainbow trout
Sales for plantings	175 020	159 450	156 661	63 903	399 504	—	717 955	159 965	542 770	119 963
Sales for breeding purposes between commercial fish breeders	21 200	32 300	142 370	220 750	177 595	189 728	418 473	224 137	459 765	405 225
Sales by fishing ponds	74 325	248 510	137 452	213 632	176 550	278 002	311 778	285 503	507 610	430 409
Sales for consumption	—	125 000	—	177 000	—	84 209	—	329 571	—	202 644*
Total	270 545	565 260	436 483	675 285	753 649	551 939	1 448 206	999 176	1 510 145	1 158 241

SOURCE: Annual reports, Pisciculture service of the Ministère du Loisir, de la Chasse et de la Pêche.

*This data does not seem to correspond to the real situation.

TABLE 4. Quantity in kilograms and revenue generated by sales of trout according to type of market in Quebec in 1981.

Species	Size	Type of market	Quantites sold in 1981 (kg)	Price/kg	Sale price in dollars ($)	Total value of sales on various markets
Brook (fry)	1 100/kg	Stocking	2 672 kg	$77/kg	$205,744	
Rainbow (fry)	1 100/kg	Stocking	Data incomplete	—	—	
Brook (fingerling)	88/kg	Stocking	12 443 kg	$27.60/kg	$343,426	
Rainbow (fingerling)	88/kg	Stocking	2 523 kg	$27.60/kg	$ 69,634	
Brook (adult)	13/kg	Stocking	41 033 kg	$ 9.26/kg	$379,433	Total plantings $1,082,230
Rainbow (adult)	13/kg	Stocking	9 069 kg	$ 9.26/kg	$ 83,993	
Brook (adult)	44/kg	Fishing pond	115 126 kg	$ 7.50/kg	$863,445	Total pond fishing $1,595.572
Rainbow (adult)	44/kg	Fishing pond	97 617 kg	$ 7.50/kg	$732,127	
Rainbow (adult)	3/kg	Consumption	68 088 kg	$ 5.28/kg	$359,500	Total consumption $359,500

Total sales in kilograms: 348 571.
Total sales[a]: $3,037,302.

[a] Sales between fish breeders are not included.

age-group sold on various markets. A summary of the total production of 1981 and its monetary value is given in Table 4.

SALMONIDAE MARKETS

Quebec trout is sold on four principal markets:

1) Planting trout

This is trout sold for the restocking of public or private waters used for recreational purposes.

2) Fish-out pond trout

This trout is sold to fishermen who fish in artificial ponds used for commercial purposes.

3) Trout for consumption

This is dead trout sold to individuals, slaughterhouses, stores, or wholesalers by the fish breeders.

4) Transactions between breeders

These transactions are to complete the breeders' stocks when demand exceeds production, to stock commercial fish ponds and new breeding enterprises, and to keep fish farms not equipped for the incubation of eggs stocked with fry.

For more information on trout market prospects, refer to Landry and Hansen (1982).

FISH BREEDING PERMITS

To date, the MLCP has issued more than 417 commercial breeding permits. However, the facilities have not all been built. Figure 1 shows the rise in permits issued from 1976 to June 1982. Each year the MLCP prepares a list of the names and addresses of fish breeding establishments in Quebec. One may also consult Anderson (1982).

There are three categories of commercial permits:

1) Category 1 permits are issued for breeding, planting, and consumption purposes.[1]
2) A Cateogry 1 plus fishing pond permit is issued to a Category 1 permit holder to allow him to operate a fishing pond.
3) A fishing pond category permit only allows the operation of the fish pond.

Having a permit does not necessarily mean that the holder will carry out all the activities he is authorized to do.

A total of 35 Category 1 permits, 267 Category 1 and fishing pond permits, and 99 fishing pond operation permits were issued in June 1982.

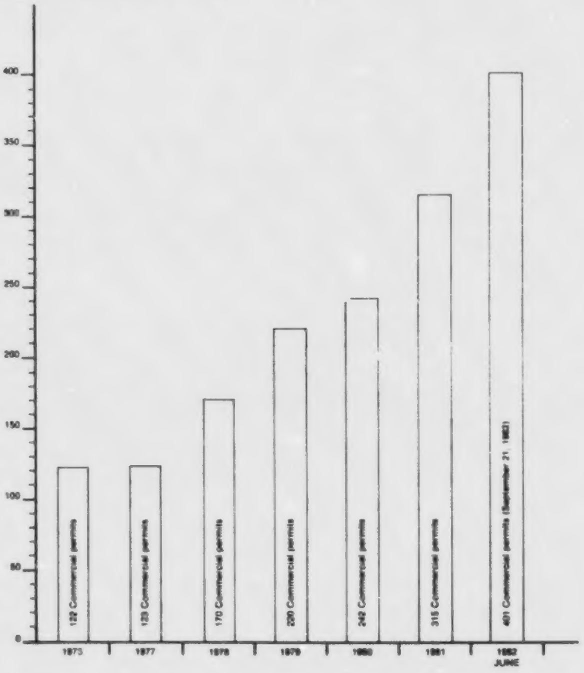

FIG. 1. Number of "commercial" fish breeding permits issued annually between 1976 and 1982.

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[1] Only rainbow trout may be sold on the market in Quebec.

The MLCP grants breeding permits for certain species of Salmonidae in accordance with the wishes of the future operator and the species distribution zoning regulations (Samson et al. 1976) (Fig. 2). The greatest number of permits issued are for the raising of brook trout while those involved in the breeding of brown trout and lake trout are less numerous because of egg supply problems (Table 5). A few breeders occasionally become involved in the raising of landlocked salmon and Atlantic salmon.

Under the joint plan, authorization to breed for marketing purposes is given by the Syndicat des pisciculteurs.

INVESTMENTS

It is difficult to precisely assess the value of capital investments by fish breeders and private financial institutions. However, considering that they are certainly equivalent to the amounts invested by the Quebec government in private fish farms ($2,500,000), we can deduce that since 1979 a minimum of $5,000,000 has been invested in the development of Quebec pisciculture (personal communication, MAPAQ and OCAQ).

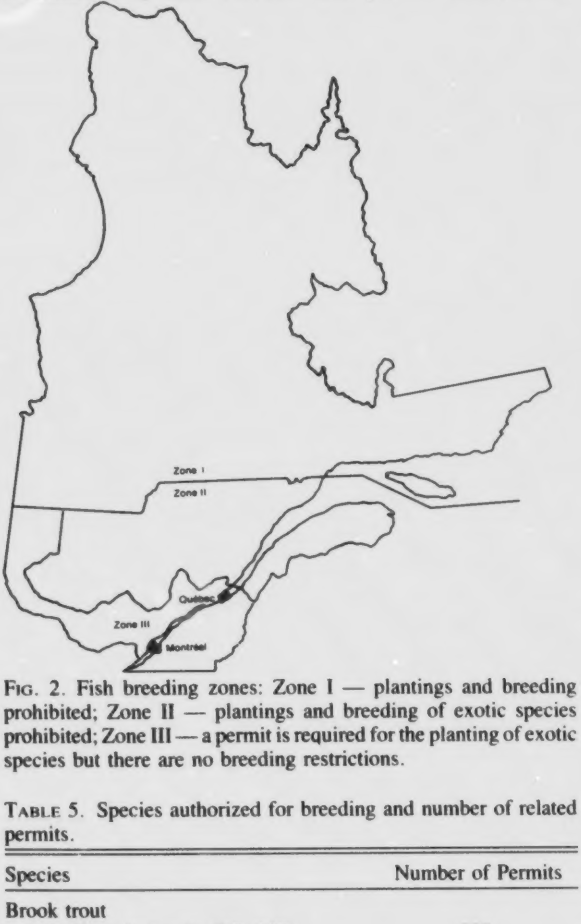

FIG. 2. Fish breeding zones: Zone I — plantings and breeding prohibited; Zone II — plantings and breeding of exotic species prohibited; Zone III — a permit is required for the planting of exotic species but there are no breeding restrictions.

TABLE 5. Species authorized for breeding and number of related permits.

Species	Number of Permits
Brook trout *Salvelinus fontinalis* (Mitchill)	372
Rainbow trout *Salmo gardneri* Richardson	264
Lake trout *Salvelinus namaycush* (Walbaum)	17
Brown trout *Salmo trutta* Linnaeus	14
Total	667[a]

[a]Several fish breeders raise more than one species.

The amounts invested by the provincial government ($2,500,000) come from two sources: the fish farm establishment program, which provides a grant of $25,000 for the construction of facilities used for fish breeding; low interest loans, loan guarantees (credit margins) and grants from the Office du Crédit Agricole du Québec (OCAQ), a Quebec Crown corporation.

Job Creation

At the present time, between 100 and 150 person/years are spent on the production of trout in Quebec, i.e. about 3.5 person/years per 10 tonnes of production. Another 50 person/years should probably be added for related activities.

TRAINING AND RESEARCH

Since 1979, a Quebec college (Cégep de Saint-Félicien) offers a complete training program for fish breeding technicians. This program, the only one available, is a 3-yr program given to persons having completed high school. However, certain institutions offering other programs occasionally discuss aquaculture in some courses. The Department of Agriculture (MAPAQ) (CPAQ, ITAA — l'Institut de technologie agricole et alimentaire) occasionally offers development courses on specific subjects.

In a few universities we find some interest in the field of pisciculture, but this interest is not reflected by structured training programs given by specialists.

The only research done in Quebec in this field is limited to fish diseases. This work is done at the Institut Armand-Frappier and the École de médecine vétérinaire de Saint-Hyacinthe. A few university researchers occasionally touch on fish breeding matters as part of some research projects.

Furthermore, the Ministère de l'Agriculture du Québec offers support structures, such as the Aquaculture Committee of the Conseil de la production animale du Québec (CPAQ), department advisory body on all matters relating to fish breeding. This committee also provides information on the newest techniques for fish farming production through symposia and/or publications. We should also mention the Conseil de références économiques d'agriculture du Québec, of which the aquaculture committee is an advisory body in regards to financial institutions. These two committees are made up of government representatives and members from the private and semi-private sector (OCAQ, teaching institutions, etc.) This diversified representation favours a greater understanding of problems encountered and of solutions to be applied.

GOVERNMENT FISH HATCHERIES

All Quebec government fish hatcheries are under the jurisdiction of the Ministère du Loisir, de la Chasse et de la Pêche. In this section, Mr Serge Gonthier of the

Aquatic Branch describes his department's policies and breeding facilities, including the species raised.

The Government of Quebec, through the Ministère du Loisir, de la Chasse et de la Pêche, operates seven fish hatcheries throughout the province. The production of these facilities is mainly used for conservation programs in public waters. It is also a source of supply of fish eggs for private breeders.

The government fish hatcheries include:

HATCHERY	TYPE OF PRODUCTION	EQUIPMENT	WATER SUPPLY
Lac des Écorces	Brook trout	Rectangular basin	Lake
Saint-Faustin	Brook trout	Circular basins	Spring
Baldwin	Brook trout	Circular and rectangular basin	Lake Spring
	Rainbow trout Brown trout Lake trout Landlocked salmon Maskinonge		
Tadoussac	Salmon	Rectangular and circular basins	Lake
		Brine holding tank for salmon spawners	
Anse Pleureuse	Salmon	Circular basins	Lake
Gaspé	Salmon Brook trout	Circular basins	River
Lac Long	Brook trout (incubation only)	Troughs	Lake

The MLCP is currently revising its fish breeding policy, the main objectives of which are:

- the conservation and protection of the wildlife heritage;
- research and development in the pisciculture sector;
- the efficiency of interventions.

In regards to the conservation and protection of the fauna, the MLCP intends to promote zoning for the breeding, transportation, and planting of fish. This approach will provide a control over species authorized for breeding and planting and over the health of the fish.

Research and development would comprise three sections:

- the health aspect;
- the selection of fish stocks adapted to various requirements;
- the development of the latest in pisciculture techniques.

Ensuring efficient interventions would mean proposing planting procedures based on stock lines, size of the fish, and type of territory to maximize the yield.

BREEDING TECHNIQUES

Egg Production

Until 1980, brook trout and rainbow trout eggs came mainly from government fish hatcheries. The MLCP, to encourage the production of Salmonidae eggs by private breeders, set up a policy of escalating prices for its eggs, over a period of 3 years.

This policy had positive results from the beginning, as about 30 breeders put eggs up for sale even in the first year.

Today, there are two large egg producers (1 000 000 and more) but several breeders produce enough to make them autonomous and, in many cases, meet local demand.

Equipment

Troughs with incubation trays are the most common. Each hatchery has developed or adopted a variation somewhere between California incubators and tray incubators with a horizontal stream of water.

In some hatcheries we find, although very rarely, vertical incubators. In addition, incubation in pails has recently been introduced.

Buildings

The incubation of eggs is done in several types of facilities, from the basements of private homes to well-designed hatcheries adjacent to other breeding facilities.

Water Supply

Water from wells dug in loose deposits and in consolidated rock are most often used for this type of production, followed by springs, although some use water from streams, with all the problems it involves.

An increasing use is being made of recirculation and thermal units to maintain higher temperatures during incubation.

Problems

The main problems encountered during incubation are:

1) bad circulation;
2) inadequate concentration of oxygen around the eggs;
3) a lack of hygiene;
4) low temperature incubation water;
5) bad quality eggs.

Fry-Rearing[2]

Fry-rearers are numerous in Quebec. Fry-rearing was the basic form of pisciculture in Quebec until the mid-1970s. Fry-rearers range from people who raise a few thousand fry in their basements as a sideline to those producing more than 500 000 fry.

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[2] For the titles of the various stages of production, see CPAQ 1982.

Equipment

The stock is usually started in wooden troughs, although some may be of fiberglass. They are often the same troughs used for incubation. Generally 30–50 cm wide by 3–5 m long and 15–30 cm deep, they are often placed in rows above the retaining tanks.

Once the fry reach 2 to 3 cm or the troughs become overcrowded, the fry are moved to the retaining tanks.

There are several types of tanks. The most popular are made of concrete. They are about 1 m wide by 5–9 m long and 60 cm deep. They often catch water from the troughs suspended above them (Paulhus 1972).

Tanks of prestressed concrete, sold in sections 60 cm wide by 2.4 m long and 60 cm high, are found in most hatcheries built since 1980 (Les entreprises Jeandeau Inc.).

Circular tanks and Swedish-type rectangular tanks may also sometimes be seen.

Water Supply

Brook trout are often reared in the same type of water as that used for incubation. Ground water may be used at this stage of production, depending on its temperature variations. Recirculation and heating of water are also very popular in this type of production.

Problems

The problems encountered at this stage include:

1) overcrowding;
2) problems related to feeding;
3) supersaturation;
4) inadequate concentration of dissolved oxygen;
5) ammonia (NH_3) intoxication;
6) hygiene, health problems, lack of experience...

The most frequent causes of mortality among fry are related to respiratory troubles. The lack of dissolved oxygen is not the only reason for this physiological condition. Irritants such as ammonia (NH_3), suspended particles, bacteria (flexibacter), and parasites are often responsible for this condition.

Fingerlings and Adults

The rearing of fingerlings is mainly done from the spring to the fall, making it possible to use outdoor facilities.

Equipment

Even today we still see many earthen ponds. They are rectangular basins of varying lengths (6–15 m), 1–3 m wide and with an average depth of 60 cm (45–120 cm), or multiple configuration basins (small ponds) 2–4 m in diameter and with an average depth of 90 cm. They generally have a downstream sluice-gate. When they are set out in rows, a more or less functional waterfall separates them. Since 1975 the exploitation of these facilities has been improved by the use of surface aerators.

These basins have a low self-cleaning potential. They must be regularly drained to clean them of manure that accumulates in considerable quantities around the surface aerators, in the dead water areas and on the downstream side. These accumulations make handling dangerous and often give a bad taste to fish and can even result in death by intoxication.

This type of basin is often invaded by weeds and microscopic and macroscopic algae, but less obviously than in the growth ponds.

Water Supply

Same source as those previously mentioned, although water from streams and rivers is more often used.

Growth Ponds and Fishing Ponds

Ponds are very popular installations in Quebec. It is almost true that every farmer who has a source of water or a small stream has set up a fish pond.

In addition, fishing in ponds is very popular in Quebec and constitutes an important market for growing trout. Several hundred fishing ponds have sprung up in the last 5 years. Unfortunately, many of them are badly designed, which leads us to say that many of them are the bane of fish breeding, as they give the public a bad impression of the quality of fish farm products (Hansen and Landry 1982).

Artificial ponds have an area of ¼–3 ha. They are often extensively exploited. The average depth is 2 m. The substrate may be of sand, gravel, clay, or of synthetic materials. Surface aerators are commonly used in this type of operation.

Water Supply

The water supply for these ponds may come from one or several of these sources:

1) water from a stream or river that was diverted;
2) spring;
3) well (aquifer);
4) ground water table by infiltration;
5) land drainage system;
6) waste water (hatchery).

Problems

The main problems encountered in this type of facility are:

1) oversized ponds;
2) insufficient rate of exchange;
3) overstocked pond;
4) overheating of water;
5) asphyxiation problem (at night) (algae blooms);
6) intoxication by ammonia and other toxins produced by algae and/or bacteria;
7) off flavor;
8) harvesting difficulties;
9) problems related to accumulation of waste;
10) winter feeding problems;
11) predation;
12) health problems.

Although the review of ground basin and artificial pond operations is rather pessimistic, one should not think that all these facilities are bad. There are several breeders who succeed in operating these facilities and providing a first-quality product. It's all in the way you do it!

Concrete Basins

The "race way" is found in most new fish farms. It may be built on the site or prefabricated.

Prefabricated basins are of reinforced concrete and are available in sections 2.4 m long, 2.4 m wide and 1 m high. They are laid out in race ways 15–36 m long and are either used as combined basins or in rows of two to four basins, depending on the quantity and quality of the water available. These basins have the advantage of being portable and easy to install.

The use of these basins by private companies is increasing. In Quebec, they are only available through Entreprises Jeandeau Inc., Scotstown, Que. and Aurèle Marois Inc., 324 St-Ignace St., Montmagny, Que. G1V 1S7. Entreprises Jeandeau produces several sizes of rectangular basins and several types of fish breeding equipment. Aurèle Marois Inc. builds fiberglass basins of various forms and sizes on order.

"Home-made" concrete basins of reinforced concrete are about 16–40 m long, 2.4–3 m wide, and 1 m deep. Two to four basins may be joined and operated in rows of two to five basins.

A sedimentation space of 1–2 m long is generally provided for each basin. This allows them to maintain a better quality of water in downstream basins.

If possible, a waterfall is placed between the basins, and in some instances fish breeders use various U-tubes. When natural oxygenation between basins is not sufficient, surface aerators and bubble aeration are used.

These concrete basins are often covered by greenhouses or a building. This allows breeders to efficiently exploit these basins in the winter, especially if a source of hot water from an underground water table or the ground table is being exploited.

This type of basin, when joined to an efficient sedimentation basin and a U-tube system, will allow an optimization of production. In some cases they obtain charges of more than 100 kg per cubic metre per hour.

Water Supply

Once again it may come from several sources for a same farm:

1) water from a stream or river;
2) water;
3) ground water table;
4) aquifer;
5) land drainage system;
6) lake.

Problems

When properly exploited, these basins eliminate most problems encountered with other systems. However, in some cases there may be design problems.

The main problem is that of the excessive size of the tanks or the number of basins in regard to the quality and quantity of water and the reoxygenation facilities between these basins. This leads to:

1) insufficient self-cleaning;
2) insufficient oxygenation;
3) abnormal accumulation of metabolic products.

Circular Basins

These basins are rarely used in the private sector. Made of concrete or fibreglass, they are used mainly for the rearing of fry.

Silos

Silos are used experimentally in two fish farms. This type of basin has numerous technical advantages and seems very promising for the rearing of trout of more than 15 cm, according to the experience of one of the authors.

Aeration in General

The reoxygenation of water is generally provided by waterfalls, surface aerators, diffusors, and in a few cases by U-tubes.

Waterfalls

They are found between basins set in rows and are generally inefficient. Mechanical aerators must be used to make up for their deficiencies.

Surface Aerators

They became popular between 1975 and 1981. They are mainly used to aerate ponds and basins of more than 3 m in width, they can meet the breeder's needs if properly maintained. However, they are difficult to use in the winter and the protective basket tends to plug up quickly, hindering their efficiency. They are also difficult to operate in basins of 2.4 m or less in width. In addition, they lead to considerable accumulations of waste in rectangular basins. This equipment is manufactured by several enterprises in Quebec.

Diffusors

Various types of diffusors have appeared since 1980. They are used where surface aerators are difficult to operate. Mid-sized and small bubble diffusors are mainly used. The former have been found to be inefficient but have a long life, while the latter, while very efficient, do not last long (1–2 months). The cost of purchasing, installing, and replacement being very high, the diffusors have only had a limited success and today are shunned by fish breeders.

A promising type of homemade diffusor using Tyvek® (Dupont Co.) tubing is very popular (Mitchel and Kirby 1976).

U-Tubes

This is a new use of an old aeration technique. The U-tube is no doubt the most efficient and profitable aeration technique of all those mentioned (Petit and Maurel 1982). However, it requires serious precautions. When badly designed, the U-tube system is inefficient or may lead to serious oversaturation problems. This type of aeration is mainly found in new operations since 1980.

Liquid Oxygen

New techniques using pure oxygen are starting to be used in fish breeding in Europe and the United States. They offer interesting possibilities. There are even prototypes of oxygen generators (with a zeolite base) that could hasten the use of pure oxygen for fish breeding and make it profitable. It is probably in this direction that practical research in oxygenation should be oriented.

Generators and Alarm Systems

The majority of fish farmers have generators powerful enough to at least meet minimum needs during electrical failure. The systems are usually linked to alarm systems that warn the breeder in case of power outages.

Some have more elaborate alarm systems with 10–100 monitors spread throughout the fish farm to watch out for power outages, motor breakdowns, water levels, etc. (Jocelyn Nadau, 606 Drouin, B.M. 67. St-Louis de Pintendre, Que. G0R 2K0).

Feeding

Most breeders feed their trout by hand. Automatic feeders are almost exclusively found in government hatcheries. Since 1981, a few breeders are trying out demand feeders.

There are currently four suppliers of trout meal to Quebec, Martin Feeds and Ewos of Ontario and Ralston Purina and Silver Cup of the United States. Recently a Quebec agri-food cooperative, Nutribec, has been trying to produce trout meal on an experimental basis.

HEALTH

Until the mid-1970s, fish breeders in Quebec probably only knew about infectious necrosis of the pancreas and a few widespread infectious diseases such as *Saprolegnia* infections, parasites, *Aeromonas hydrophila*, and myxobacteria. More serious diseases such as furunculosis and perhaps kidney disease seems to be endemic to a few rare sites.

After 1975–79, Quebec fish farming industry grew considerably. The market changed and exchanges between breeders increased (Tables 2, 3, and 4). Unfortunately, for a number of reasons the government of Quebec and of Canada, in spite of demands, have not yet entered into a health program in Quebec.

Today, furunculosis and, to a lesser extent, kidney disease have spread to numerous locations in Quebec (personal communication, Veterinary services, MAPAQ).

OTHER PRODUCTIONS

For the moment, the production of trout is the only aquacultural activity in Quebec.

However, there are three projects that could diversify this production in coming years:

The raising of Atlantic salmon in sea water, which is currently at the design level;

The rearing of young salmon for planting purposes, a project sponsored by the Ministère du Loisir, de la Chasse et de la Pêche; a few fish breeders are already testing it;

Mussel breeding: this project is also at the research stage, and will probably by operated in the Îles de la Madeleine (Poirier 1975; Poirier et al. 1978). In 1981, the Institut national de la recherche scientifique (INRS — océanologie) started an aquaculture station at Pointe-au-Père. This center stimulates the development of marine aquaculture in Quebec.

CONCLUSION

Fish breeding in Quebec is at a critical and transitory period in its history. Traditional markets are saturated and so the harmonious development of future new markets is essential to ensure the survival of the industry. The marketing plan set up by the Syndicat des pisciculteurs du Quebec may be a first step towards this objective.

However, the most positive elements for the development of Quebec fish breeding industry may be the major role played by the Ministère de l'Agriculture, des Pêcheries et de l'Alimentaiton du Québec versus private producers. This transfer of jurisdiction has enabled the Department to offer to breeders integrated services such as: local and regional technical assistance, agro-alimentary programs, diagnosis services, etc. It must be pointed out that these administrative adjustments are the result of a policy strongly promoting food self-sufficiency. Trout production development policies are part of this major objective and orientation.

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AQUACULTURE IN BRITISH COLUMBIA

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ABSTRACT

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This paper presents an overview of the current status of aquaculture in British Columbia. To date, total production from the culture of invertebrates, vertebrates, and marine plants has been small and disappointing; it has generally decreased in recent years. In 1981, oyster production was about 1 400 metric tons (t) and farmed salmon only 180 t. Reasons for this low production are presented. The future of aquaculture in British Columbia nevertheless remains promising and there is the potential to establish a viable mariculture industry in the Province. Research and development needed to achieve this goal are discussed.

INTRODUCTION

Aquaculture, or its more limited form, mariculture, continues to captivate the interest of the public, industry, academia, and governments. The recent Pearse report (Pearse 1982), which was commissioned to analyse and suggest possible solutions to present problems in the West Coast fishing industry, devoted a chapter to aquaculture and recommended that Fisheries promote the development of mariculture on the Pacific coast. Interest in aquaculture in British Columbia continues to increase even though past production and profits from aquaculture operations in Canada generally have not been large or encouraging.

In 1973 a conference was held in Winnipeg to discuss development of an aquaculture policy for Canada and much of the information and literature on the subject to that time was reviewed (MacCrimmon et al. 1974). The present paper is not a review of developments since that time but is an assessment of the current state of aquaculture and its potential during the next 5–10 yr in British Columbia. Major emphasis is on mariculture, since more interest and greater potential exists there than in freshwater culture.

The physiography and oceanography of British Columbia appear to be highly favourable for the development of a variety of mariculture operations. The coast is much indented with many islands and inlets, giving a total coastline of about 27 000 km. There is much protected water between the many islands and the mainland, between the islands themselves, and in numerous sheltered bays and inlets. Waters along the coast are temperate and open throughout the year; ice formation is rarely a problem except under local conditions (Thomson 1981). The waters are productive and relatively free of pollution except in some specific areas in the Strait of Georgia. The much indented coastline makes local oceanographic conditions complex and these can be of great importance to the mariculturist, since there can be significant variations in oceanographic conditions within a distance of 1–2 km. The mountainous terrain makes communications difficult and frequently expensive. There are few roads, and travel along the coast must freqently be by boat or air; this is particularly true for many isolated coastal communities where aquaculture might provide much needed employment and income. Most of the Province's population of 2.7 million is concentrated in the southwestern corner, in the Vancouver–Victoria area, which is the major local market. High labour costs and difficulties in obtaining equipment or marketing products because of the poor and expensive communications system create further problems. All these factors must be considered carefully when assessing the mariculture potential in the Province, since they affect the profitability of any operation.

Aquaculture and mariculture have been defined in many ways. The terms as used here mean culture of aquatic organisms with private ownership during some or all of its life to insure sole ownership at the time of harvest. Not included in this definition are such broad forms of aquaculture as stocking lakes with trout, government salmon hatcheries, salmon enhancement programs, or programs to enhance a common property resource, except where these impinge on aquaculture or where technology from these endeavours is applicable or has been used in aquaculture projects.

INVERTEBRATES

British Columbia has a rich invertebrate fauna but few species are harvested commercially and fewer have been cultured or offer potential for culture. The species available for culture are limited. Several criteria must be considered when deciding if an animal is suitable for culture; three of the most important are an inexpensive and plentiful source of juveniles (seed), a rapid growth rate (or reasonably so), and a high price for the product.

Most invertebrate culture has been with molluscs, particularly bivalves, and there is a long history of bivalve culture in many parts of the world. In British Columbia there are approximately 800 species of molluscs along the coast (Bernard 1970) but only eight are harvested commercially and only one cultured to any extent.

Oysters

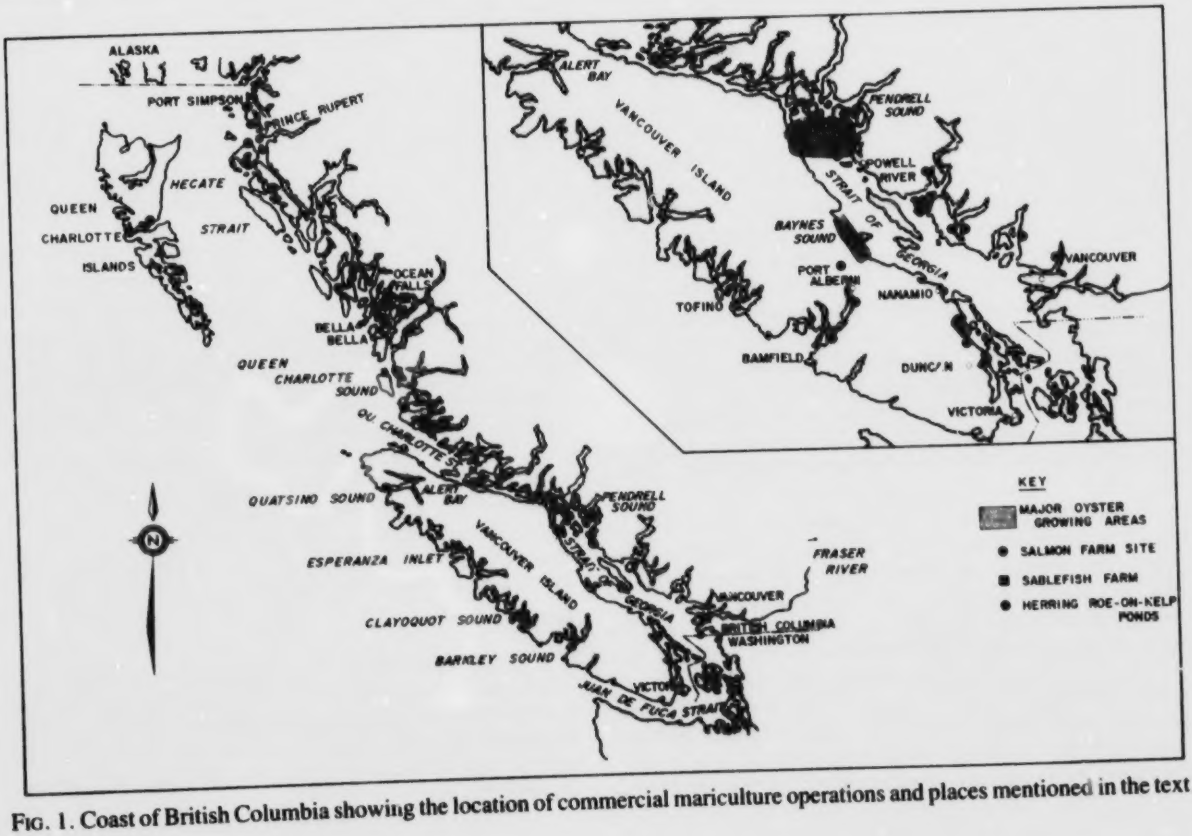
Oysters have been cultured for a longer period than any other organism on the coast. Extensive research studies have been carried out on the resource, and the industry, which is primarily a farming operation, has been the subject of several studies and reviews to assess its problems and potential (Fralick 1979).

Three species of oysters occur in British Columbia and all have entered the fishery. The native oyster, *Ostrea lurida*, occurs throughout the British Columbia coast (Bernard 1970) in widely scattered locations. A fishery for wild stock began in 1884 and continued until about 1936; the species was never fully cultured as in Washington State. Slow growth, small size, and high labour costs porbably preclude culture of this species in British Columbia. Eastern oysters, *Crassostrea virginica*, were first imported into British Columbia in 1903 and annual plantings continued until about 1940. Breeding was limited, the species did not spread, and it has no potential for culture in the Province. Pacific oysters, *C. gigas*, were first introduced into the Province in 1912 or 1913 and low level introductions continued for a few years. In 1925, two thousand 2- to 3-yr-old adults were imported from Washington State and 20 cases of seed from Japan (minimum 240 000 seed oysters). This marked the beginning of the industry; about 624 million seed cysters were imported by the industry over the 35 yr (Table 1).

The oyster industry is centred in the southern part of the coast, mostly in the Strait of Georgia (Fig. 1), and most production comes from intertidal bottom culture on ground

TABLE 1. Imports of Pacific oyster seed (in cases) from 1925 to 1978. Source of seed is Japan unless otherwise noted.

Year	No. of cases	Year	No. of cases	Year	No. of cases	
1925	20	1941	3 065	1960	909	
1928	40	1947	2 192	1961	1 000	
1929	300	1948	2 675	1962	1 000	
1930	43	1949	4 804	1963	Nil	
1931	127	1950	5 204	1964	Nil	
1932	189	1951	5 400	1965	25	
1933	589	1952	3 584	1966	Nil	
1934	625	1953	1 425	1967	90	
1935	79	1954	1 516	1968	300	
1936	207	1955	1 609	1975	50	(U.S.)
1937	221	1956	3 240	1976	627	(U.S.)
1938	912	1957	3 342	1977	1 200	
1939	1 060	1958	3 348	1977	630	(U.S.)
1940	602	1959	1 290	1978	8.3	(U.S.)


ALASKA
PORT SIMPSON
PRINCE RUPERT
HECATE
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QUEEN
CHARLOTTE
ISLANDS
OCEAN FALLS
BELLA BELLA
QUEEN
CHARLOTTE
SOUND
QU. CHARLOTTE ST.
QUATSINO SOUND
ALERT BAY
PENDRELL SOUND
ESPERANZA INLET
VANCOUVER ISLAND
STRAIT OF GEORGIA
FRASER RIVER
VANCOUVER
BRITISH COLUMBIA
WASHINGTON
CLAYOQUOT SOUND
BARKLEY SOUND
VICTORIA
JUAN DE FUCA STRAIT
N
ALERT BAY
VANCOUVER ISLAND
PENDRELL SOUND
POWELL RIVER
STRAIT OF GEORGIA
BAYNES SOUND
PORT ALBERNI
VANCOUVER
NANAIMO
TOFINO
BAMFIELD
DUNCAN
VICTORIA
KEY
MAJOR OYSTER GROWING AREAS
● SALMON FARM SITE
■ SABLEFISH FARM
● HERRING ROE-ON-KELP PONDS

FIG. 1. Coast of British Columbia showing the location of commercial mariculture operations and places mentioned in the text.

leased from the Provincial Government (Quayle 1969; Quayle and Smith 1976). Seed is either held for a year on seed ground or spead directly on growing areas and the oysters harvested when 3 yr or older. Recently, some production has resulted from pin or stake, floating or suspended, and tray culture. Most of the producution is shucked and sold fresh, but recently a half shell trade from tray culture has developed (Table 2).

TABLE 2. Number of single half-shell Pacific oysters landed in British Columbia, 1947–81.

Year	No. of oysters (dozens)
1974	22 467
1975	35 031
1976	34 786
1977	40 344
1978	31 635
1979	35 819
1980	41 352
1981	63 764

Commercial operations are small family enterprises and the majority of leases are under 10 ha. The number of lease holders has increased over the past years to 139 and the area under lease to 1 210 ha (Table 3). The number of people employed by the industry is in the neighbourhood of 300, some on a part-time basis.

Procurement of seed was a problem for the industry. Pacific oysters in British Columbia are at the periphery of their breeding range on the west coast of North America, and general breeding is erratic, primarily because of low summer water temperatures. Widespread breeding has only occurred in 1942, 1958, and 1961, although limited local breeding occurs more frequently. Initially, seed was imported annually from Japan (Table 1). In 1948 an area was found in the Strait of Georgia, Pendrell Sound, that has unique oceanographic conditions that permit consistent breeding in sufficient quantities to meet industry needs particularly if seed is stockpiled in years of abundance. Other areas exist where breeding is somewhat less consistent, but they provide back-up areas for seed. In addition, seed is available from hatcheries as either spat or eyed larvae for setting at a growers facility. The availability of Pacific oyster seed is not a problem for the British Columbia industry; sufficient seed is available for the present and a greatly expanded industry.

Production has closely followed general breedings, it increased from about 800 metric tons (t) in 1940 to a peak of 6 195 t in 1963. Since then it has declined steadily, and in 1981 was 1 415 t (Fig 2). The 1942, 1958, and 1961 breedings had both beneficial and detrimental effects on the industry and altered oyster farming practices. After these breedings, large quantities of wild oysters were available to growers and many began to harvest them in addition to, or instead of, seeded oysters from their leases. When wild oyster stocks fell below commercial levels, production fell because there was little stock on their leases. The situation was prolonged by a hope that another general breeding would occur but none did after 1961 and most leases have been underseeded since then. Wild oysters are still harvested but at a low level because of reduced stocks (Table 3).

The potential for oyster production in British Columbia is substantial. The amount of suitable bottom in the southern

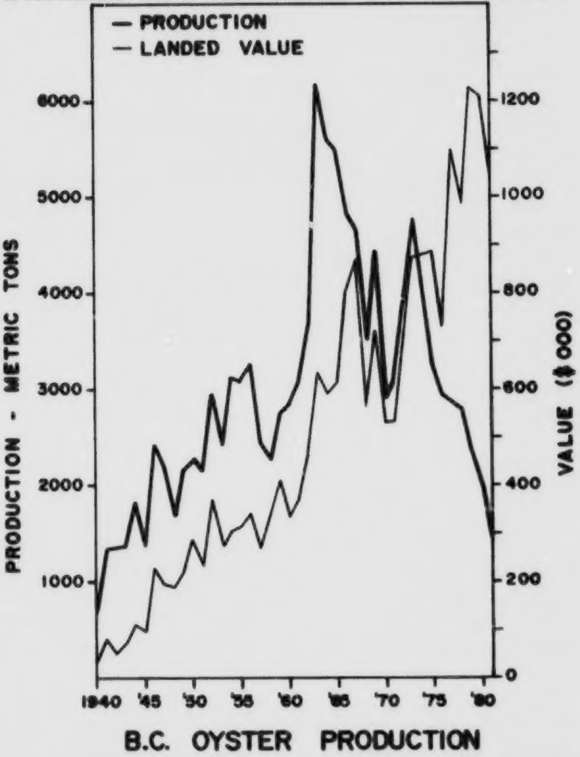

FIG. 2. British Columbia Pacific oyster production (round weight) and value ($000), 1940–81.

TABLE 3. Number of lease holders, area under lease, permits for picking wild oysters, and amount and value of wild Pacific oysters harvested in British Columbia, 1974–82.

	1974	1975	1976	1977	1978	1979	1980	1981	1982
No. of lease holders	64	65	68	65	81	87	99	114	139
Total areas under lease (ha)	763	770	725	698	859	895	1087	1157	1 210
No. of picking permits	—	96	124	87	83	74	62	73	
Wild oysters picked (t)	—	1 220	797	183	725	643	260	172	
Value of wild oysters ($000)	—	263.6	175.8	402.0	159.8	141.8	206.8	137.2	

part of the Province is limited (about 1 000 ha, Quayle 1969) but some marginal ground can be utilized with other types of culture. Ideal conditions exist throughout the Province for floating or suspended culture (Quayle 1971), the type of culture used almost exclusively in Japan and Korea. Production per unit area can be increased up to 25 times, and a conservative estimate of annual production from 610 ha in the Strait of Georgia using this type of culture is 70 000 to 110 000 t whole weight. This culture method is well suited to other parts of the coast including the central and north coasts where Pacific oysters can be grown. However, slower growth rates and distance from markets may make it economically unattractive although processing could be done in the north. A recent project by the industry has attempted to raise a limited production by suspended culture; results of this project are just being realized.

The obvious question is why has oyster production not increased dramatically in British Columbia, particularly in light of all the research, reviews, and substantial government funds that have been spent on the industry. Acquisiton of seed, biology, and culture technology are well developed although some techniques may have to be adapted to suit local requirements. The British Columbia industry has not suffered from devastating diseases such as those experienced on the Atlantic coast, although Denman disease can be important in local areas (Quayle 1960). Although British Columbia waters are relatively unpolluted, some oyster-growing ground has been closed or restricted because of it.

The decrease in production is primarily due to underutilization of leases, poor farming practices, and insufficient seeding. Quayle (1969) stated that 1 ha of oyster ground should produce 18–28 t (whole weight) annually (200–300 gal/acre); in 1981, average production was less than 1.4 t/ha. If the industry is to expand, a much heavier seeding program must be undertaken on existing leases and suspended culture widely adopted; good farming practices must be carried out in all phases of culture. A major reason the industry has not undertaken these programs is apparently because the profit margin is too small to permit borrowing of capital. The industry can continue as a cottage industry, but if it is to expand it may have to consider forming larger units or a strong central agency with a large central processing and marketing facility, as in Japan. This would permit growers to remain on their leases, farm oysters, and increase production. A large processing plant could develop new processing methods and markets and the strong central agency could influence government policy and provide a better base for borrowing capital for expansion.

The suggeston has been made of introducing another species of oyster to the coast, particularly for culture in the central and northern areas. Many species have been considered but none has any advantage over the Pacific oyster.

Increased production will probably require government involvement to prevent the spread of pollution and to improve the leasing system to insure growing areas are preserved. The immediate problem for expansion of the industry appears to be economic, and programs to provide low interest loans to growers may have to be considered.

Widespread enhancement of oyster stocks for public use has not been practised in British Columbia except for a few minor transfers. Present Provincial Government policy allocates much of the wild oyster resource to the recreational fishery. Enhancement of oysters for the general public would essentially require the government to become involved in the oyster farming business.

The oyster industry has been in a decline since the peak year of 1963 but interest in the industry continues, since the number of people getting into the business increases each year (Table 3). The potential for the industry is substantial and can be achieved with existing biology and technology, but changes suggested above are required to increase production. If a thriving oyster industry cannot be established in British Columbia it is unlikely that any other marine invertebrate can be cultured economically in the Province.

Mussels

Two species of mussels occur intertidally in British Columbia, blue mussel, *Mytilus edulis*, and sea mussel *M. californianus*; the former occurs along the entire coast whereas the latter is confined to a more oceanic environment. Sporadic attempts have been made to harvest wild stocks of both species but landings have been small.

Experimental culture of blue mussels was untertaken in British Columbia, adapting the well-proven string and sock methods (Quayle 1978; Heritage 1983); all culture attempts were in the southern part of the Province. Blue mussel seed is abundant and can be obtained from great masses of juveniles on rocks along the coast. Growth was good; 10-mm mussels put out on rafts in the spring attained a commercial size of 50 mm (shell length) in 12–14 mo. A production of 35–50 kg/2 m of rope was realized in this time.

Following these experimental trials a few attempts were made at commerical culture but production to date has been small. At present there are five growers with leases totalling 15 ha culturing mussels, most in conjunction with oyster operations.

Three major problems have prevented a large-scale commercial mussel culture industry developing in British Columbia.

1) A variety of organisms foul mussel strings, particularly barnacles and sea squirts, and cause processing difficulties, particularly for the fresh market.
2) Unexplained, heavy summer mortalities of large mussels, 35–50 mm, i.e. just smaller than commercial size. Mortalities of 80% are common and up to 100% not infrequent.
3) Heavy predation by wintering flocks of ducks, particularly surf and white-wing scoters, *Melanitta perspicillata* and *M. fusca*, and common and barrows goldeneyes, *Bucephala clangula* and *B. islandica*.

If these problems are solved a substantial blue mussel culture industry could develop, since the technology exists; an annual production of several thousand metric tons from only the southern area is not unrealistic. This would be particularly true if suspended oyster culture was widely adopted, since culture of both species of bivalves could be carried out with similar equipment in the same location. There are limited local markets, at present a minimum of 3 t/wk in the Vancouver–Victoria area, but they could be greatly expanded with guaranteed production, a vigorous marketing campaign, and new processing techniques.

Experiments are underway to culture sea mussels but results are preliminary and it will be several years before the potential for culture of this species can be assessed.

Clams

The intertidal area of British Columbia is limited because of the precipitous nature of the coastline. Large intertidal beaches are uncommon but there are numerous small beaches with clam populations along the coast (Quayle and Bourne 1972). Four species of clams have been harvested for many years: butter, *Saxidomus giganteus*; littleneck, *Protothaca staminea*; manila, *Tapes philippinarum*; and razor, *Siliqua patula*. Two species of horse clams, *Tresus capax* and *T. nuttalli*, have been harvested occasionally, both inter- and sub-tidally, and recently a substantial fishery has developed for geoducks, *Panope generosa*. Landings of most species have fluctuated greatly, frequently because of socioeconomic conditions.

Clams have been cultured for many years in parts of the world but production is limited (Mottet 1980b). Seed is taken from areas of abundance and spread for grow-out in areas where growth is faster. Experimental attempts have been made at clam culture in British Columbia but results were not encouraging; some work was done with butter clams but most was with manila clams, an exotic accidently imported into the Province in the early 1930's (Bourne 1982). Recent work in Washington State indicates that experimental manila clam culture was marginally economic in one area but not in another (Anderson et al. 1982). There have been a few minor attempts at commercial clam culture in British Columbia but production to date has been nil.

A major problem in clam culture is the acquisition of seed. In British Columbia no areas are known where quantities of natural clam seed can be collected consistently; hence, it must be bought from hatcheries, which is expensive. Natural clam spatfall may be increased by construction of artificial barriers and baffles or by spreading netting on the surface of the intertidal area (Mottet 1980b), but this does not appear to be economically viable in British Columbia. A further problem is that clam seed planted in intertidal areas must be protected, usually with some type of netting, or heavy mortalities of upwards of 95% are frequently experienced mainly from predation by crabs and fish. Further difficulties are slow growth rates (5 yr for butter and 3 yr for manila clams to reach commercial size under optimum conditions), low prices paid for clams, and the fact the aquaculturist would have to compete with the wild harvest that does not have culture costs.

Other species have been considered as candidates for culture. The littleneck clam is harvested extensively but seed is not available and problems encountered in manila clam culture would also exist in culture of this species. Culture of other commercially harvested clams does not appear to be economically viable at present. Consideration has been given to the importation of exotic species cultured elsewhere (Mottet 1980b) but none appears suited to British Columbia conditions.

A current experiment in polyculture is raising manila clams and Pacific oysters on the same ground. These two species appear well suited for joint culture, since they can occur at similar intertidal levels and require 3–4 yr from time of planting to harvest. Another current project is the culture of manila clams in floating containers, either to market size or to produce larger sized seed that might not require extensive protection when planted in intertidal areas.

Clam culture in British Columbia is technologically possible at present and could be practised along the entire coast, but it does not appear to be economically viable. Widespread enhancement of wild stocks does not seem warranted, at least not in the immediate future, because of heavy seed mortalities and high costs. Under present conditions, culture costs would have to be markedly reduced to permit widespread clam culture, but this may be surmounted with future research.

Economically viable clam culture might be hastened with development of nurseries where clam seed would be taken from hatcheries, grown quickly to a larger size, and then sold to mariculturists. Planting larger sized juveniles could reduce mortalities and harvest would be realized in a shorter time, 1–2 yr for manila clams. Research in the field of bivalve nurseries is required before the feasibility of such a procedure can be assessed.

Scallops

Extensive surveys show there are several species of scallops along the British Columbia coast (Bernard 1983) but only four are large or occur in abundance (Bourne 1969): weathervane, *Patinopecten caurinus*; rock, *Hinnites giganteus*; pink, *Chlamys rubida*; and spiny, *C. hastata*. Erratic distribution and small population size preclude any extensive sustained fishery but local populations may support minor fisheries; to date, landings have been so small they have not been recorded in Department of Fisheries and Oceans statistics.

Considerable interest exists in scallop culture in British Columbia due in part to high prices and the impressive success achieved by the Japanese (Mottet 1980a; Taguchi 1977).

Experimental work is currently underway to investigate the feasibility of culturing these four species in British Columbia. Major emphasis is on weathervane scallops, since they probably have the most potential for commercial culture; they are a large scallop and attain a harvestable size (120 m shell height) in 4 yr. Rock scallops are also large and occur along the entire coast. California studies indicate they may have potential for culture and can achieve commercial size in 2–3 yr (Leighton and Pleger 1981). Pink and spiny scallops are small (maximum size 85 mm shell height at 4–5 yr old), but they could have potential if a market for whole scallops develops. A major problem in establishing a culture operation with any species will be a consistent supply of seed. Limited amounts of natural seed of all four species can be collected but it is doubtful if the seed can be collected in sufficient amounts or with consistency for widespread culture operations. Initially, seed will probably have to be raised in hatcheries.

The feasibility of culturing two exotic scallop species in British Columbia is being investigated: sea scallops, *Placopecten magellanicus*; and Japanese scallops, *Patinopecten yessoensis*. Brood stock is brought in under quarantine conditions and only the offspring will be planted.

Scallops could be grown along the entire coast using methods employed in Japan, and scallop culture may have potential in British Columbia but it will be several years before the economic viability of the operation can be assessed.

Abalone

The northern abalone, *Haliotis kamchatkana*, is widely distributed in British Columbia and is the only species of gastropod harvested commercially in the Province. Modest centres of population exist that supported minor landings until 1975. These landings increased dramatically to over 400 t in 1977 (Bernard 1982). Since then, quotas have been introduced and annual landings are now about 70 t. Growth is slow. It requires 7–10 yr to reach commercial size (100 mm shell length); recruitment is low and probably sporadic (Breen 1980).

Abalone have been cultured for many years in Japan and California and a considerable technology has developed which could readily be adapted to British Columbia conditions. Hatcheries have been built in those two countries and juveniles either raised to commercial size in closed systems or on leases, or put out in the open environment in enhancement programs.

In British Columbia demand exceeds suppply and there is considerable interest in abalone culture and enhancement. A few entrepreneurs have been granted culture licenses. Collection of large quantities of natural juveniles is not possible and any culture operation will require a hatchery for seed production, which could then be put out on leases or released to the open environment.

In 1980, a privately owned abalone hatchery was built in British Columbia with some government support as a pilot plant project to determine the feasibility of abalone culture in the Province. Initial production was in 1980 and the aim is to produce 500 000 juveniles annually. Abalone could be grown throughout the Province but slow growth rate, high natural mortality, and the cost of producing juveniles may make it unattractive at the present time. There is a market for small abalone, 5–6 cm in length, which could be attained in 2–3 yr of culture and this could partially offset costs for producing larger sized animals.

It will be several years before the feasibility of abalone in British Columbia can be assessed.

Crustaceans

CRAB

One species of crab, the Dungeness crab, *Cancer magister*, is harvested commercially in British Columbia. Its distribution is spotty and landings have fluctuated because of population abundance (Bernard 1982), but generally, wild stocks have been sufficient to meet market demand.

No attempts have been made at crab culture in British Columbia. A California project investigated the feasibility of holding crabs of the penultimate legal size in impoundments through a moult. They were fed to hasten attainment of optimum meat content at which stage they could be marketed before the seasonal commercial fishery began and thus realize a premium price. However, the conclusion was that this practise was not economically viable.

Crab culture or crab enhancement does not appear to be economically realistic for British Columbia for the immediate future. The larval period is lengthy (100 d minimum) and difficult, growth is slow, at least 4 yr to commercial size, and natural mortality is high.

SHRIMP AND PRAWN

Eighty-five species of shrimp inhabit British Columbia waters (Butler 1980) but only 5 enter the commercial fishery; the most important is the smooth pink shrimp, *Pandalus jordani*. Shrimp enhancement is practised in Japan. Hatchery-raised larvae are released to the environment but there is little information on the benefit to the fishery. No culture or enhancement has occurred on the west coast and it is doubtful if any form of shrimp culture is realistic for British Columbia in the immediate future.

One species of prawn, *Pandalus platyceros*, is harvested in both the commercial and recreational fisheries in British Columbia, mostly from the deep inlets (Butler 1980). Attempts have been made to culture this species in the United Kingdom and California. Growth to a marketable size of 5 g was achieved at elevated temperatures in the United Kingdom but difficulty was experienced in maintaining brood stock because the offspring showed no ovarian development and there was no regeneration in spent gonads of imported broodstock. In California, a period of 24 mo was required to attain a marketable size of 15 g and this lengthy period along with poor food conversion made culture unrealistic (Kelly et al. 1977).

It is doubtful if shrimp or prawn culture will occur in British Columbia in the immediate future; considerable biological research and technological development must occur before it can become economically viable.

LOBSTER

The possibility of establishing a lobster, *Homarus americanus*, population and fishery in British Columbia continues to fascinate many people. Over a period from 1896 to 1971, 10 attempts were made to introduce lobsters, adults or larvae, to the Province. No sustaining populations were established although breeding and development through the four planktonic stages to the first benthic stage did occur. After the last transplant it was concluded that either a massive transplant of adults was needed or a hatchery would have to be constucted on the west coast to produce large quantities of stage 4 or 5 larvae for release to the environment if a population were to be established (Ghelardi and Shoop 1972). This does not appear to be realistic for the immediate future.

FRESHWATER CRAYFISH

The extensive freshwater resources of the Province have a diverse invertebrate fauna but commercial harvest of only one species has been attempted, the freshwater crayfish, *Pacifastacus leniusculus*. Populations of this species occur in the lower Fraser River and on Vancouver Island, and a minor fishery has existed for a few years; statistics show that landings are small (a few kilograms per year) mostly from the lower Fraser River area (L. Sunde, pers. comm.). Populations in Washington and Oregon were harvested commercially, primarily for the northern European market. The fishery did not develop in British Columbia apparently because of sparse populations and economic viability.

Experimental work was undertaken in British Columbia to investigate the feasibility of culturing this species (Mason 1974). It was intended to raise larvae to the second moult stage and distribute them to the open environment. The larval stages were long and difficult to raise in numbers, cannibalism occurred, and the venture did not appear to be economically feasible. Much more research and development work would be required to assess if culture of this species would be economically viable in British Columbia.

Invertebrate Summary

The Pacific oyster, which is an exotic, is the only invertebrate species presently cultured to any extent in British Columbia. Although the number of oyster leases and area under lease have increased in recent years, production has declined, largely due to underutilization of leases. Insufficient seed has been planted on leases and this has led to current poor harvests. In spite of the recent decline in oyster production one can be optimistic about the future of the British Columbia oyster industry. Sufficient biological knowledge and technology exist to enable the industry to greatly expand; an annual production of 100 000 t (whole weight) is not unrealistic for the future. To attain this production, different culture methods must be adopted and the industry and government must approach existing problems in a vigorous and progressive manner.

The potential for establishing an industry based on culture of other invertebrates is less certain. Blue mussels appear to be a candidate and could be grown with oysters; a few initial attempts have been made by the industry. Before this industry can develop, problems associated with fouling, summer mortality, and predation must be solved.

Initial attempts at clam farming were unsuccessful and existing technology does not appear to be adequate to permit establishment of a clam culture industry in the Province. Current projects are investigating the potential of abalone and scallop culture. Further research, along with improved technology and better economical conditions, may permit financially profitable culture of these and other invertebrate species in British Columbia sometime in the future.

Much interest exists in a crustacean mariculture industry but it is unlikely that crustacean culture has any potential in British Columbia in the immediate future.

MARINE PLANTS

The culture of seaweeds has great appeal because plants require no intricate feeding regime. Seaweeds are grown in many parts of the world, particularly in Asia where extensive areas of coastline are devoted to their culture and an extensive culture technology has developed.

About 500 species of marine algae occur along the British Columbia coast but only a few are believed to have commercial potential and include the genera *Nereocystis*, *Macrocystis*, *Laminaria*, *Cymathere*, *Porphyra*, *Iridaea*, *Palmaria*, *Gelidium*, *Gymnogongrus*, *Gracilaria*, and *Pleurophycus* (Fralick and Tillapaugh 1979). Beginning in 1975 the Provincial Marine Resources Branch undertook a program to assess the standing crop of the economically important kelp resources (Coon et al. 1979; Coon et al. 1980). Kelp resources, *Macrocystis integrifolia* and *Nereocystis leutkeana*, exceed 500 000 t (wet wt) and attempts have been made to harvest them but these ventures failed due to economic and marketing problems. Interest in kelp harvest continues and ventures are being proposed to harvest some of the resource along the coast but no culture is foreseen.

Coastal surveys have shown that wild populations of red algae are too sparse to permit economic harvest at the present time in spite of the fact that their products are in demand and command a high price (L. M. Coon, pers. comm.). Some form of culture would be required to enable a consistent production of red algae, but to date, the technology has not been developed to make this economically feasible in British Columbia.

Extensive work has been done to determine the mariculture potential of "edible seaweeds" in British Columbia, principally those species that are used to produe "kombu" a product widely used in Japan (Druehl 1981). Culture of three species has been attempted mostly in Barkley Sound: *Pleurophycus gardneri*, *Laminaria groenlandica*, and *Cymathere triplicata*. Most work has focused on the latter two species, since they show the greatest potential. *Laminaria groenlandica* can be grown on rope farms; it exhibits good growth and attained a harvestable size in a total growth period of 18 mo. Methods have been developed to produce seed of this species to insure a steady supply for a culture operation. *Cymathere triplicata* is also amenable to rope culture and is harvestable 7–8 mo after ropes are seeded. These two species have been grown at several sites along the coast with good results; growth was good and the product has been judged to be of good quality. Approximately 20 strains of the two species are now being experimentally cultured; current cloning techniques could produce strains with faster growth and better quality. At the present time there is one lease and one license for kombu culture in the Province.

Recently, experimental culture of the red seaweed, *Porphyra* sp. "nori," has been undertaken in the State of Washington. This species is widely used in Japan and is presently the most important aquaculture product there in both tonnage and value (Mottet 1980a). Technology that has been developed in Washington could be readily adapted to British Columbia conditions.

A major problem to the development of an "edible" seaweed culture industry in British Columbia is markets. Although seaweeds are widely consumed in the Orient, little use is made of them as human food in North America. The oriental market is limited if not closed to British Columbia products; if an industry is to develop in British Columbia, markets must be found in North America. At present this market is small but it might be expanded.

Marine Plant Summary

There is considerable interest in seaweed culture in British Columbia at present. The nutrient-rich, protected waters of the coast have potential for culturing species that could be used for food, phycocolloids, energy (methane production), and pharmaceuticals. However, development of any industry will depend on several factors, chief among which are acquisition of biological and production technology to make the operation financially feasible, an improved economic situation for the products, and development of a market for edible seaweeds in North America.

VERTEBRATES (FINFISH)

In the north temperate hemisphere successful and prospering finfish mariculture has developed along the coasts of Japan, Scotland, and Norway. In common with British Columbia these have well-flushed, naturally protected waters not subject to extensive icing. The chosen species for culture all show winter growth and experience optimum summer temperatures providing for rapid growth and good food-conversion efficiency. As outlined in the Introduction, oceanographically and topographically the environmental conditions of British Columbia are most favourable for mariculture. In addition, unlike Japan, British Columbia boasts an inland sea (Strait of Georgia) as yet mainly clear of any serious pollution, with a few localized exceptions. Furthermore, it abounds in marine fish species (about 250) with excellent representation within the family Salmonidae (8 endemic species) from which to choose and develop for marine culture. Environmentally and biologically the setting is propitious. There is a great challenge to do justice to the finfish aquaculture potential.

Pacific Salmon

BACKGROUND

Three species of Pacific salmon (*Oncorhynchus*) are currently being cultured by fish farmers in British Columbia. In order of preference and opportunity, these are coho (*O. kisutch*), chinook (*O. tshawytscha*), and chum salmon (*O. keta*). Although preference for culturing might be debated for the first two, eggs of coho salmon are readily available from federal government hatcheries (e.g. 4–9 million supplied annually to all sources in 1978–80), whereas chinook salmon are depressed, particularly in some regions, and restrictions of egg distribution for this species exist because of disease confinement. The culture of chum salmon is just entering the private sector on a test basis; it is the favoured species for Japanese and Russian hatcheries. Experimental marine culture of chum salmon in netpens has not proven to be too promising because of disease susceptibility (Brett et al. 1978).

Following the lead of developing saltwater netpen culture in Puget Sound, WA (Novotny 1975, 1980), the first private fishfarm license in British Columbia was issued in 1971. A year later a research program was approved by the Federal government to assess the aquaculture potential and deal with the problems firsthand by operating a small but full-scale salmon farm (Kennedy 1975, 1978). By 1982 a total of 12 salmon-farming permits had been issued (see location of farms in Fig. 1). Despite technical support and a solid foundation in freshwater culture of salmonids, progress has been wavering and uncertain, with one quarter of the companies withdrawing or, like the largest producer (Apex Bio-Resources Ltd.), entering receivership in 1982. Of the balance, three have yet to produce a marketable product, whereas the remaining six are either showing a profit (one) or likely to show some margin of profit (five) by 1983 or 1984. The history of salmon farming in Puget Sound is not dissimilar, with only the major producer[1] surviving from a total of six farms.

With the exception of the extensive and dominating position of Apex Bio-Resources Ltd. (now split into two smaller companies), which at its 1981 peak suported 45 full-time and 25 part-time personnel, British Columbia salmon farming is essentially a cottage industry with three to five employees per farm together with some additional seasonal help. Although suitable for Native Peoples, such fish-culture programs as have been started have switched to being a part of the government-sponsored Salmonid Enhancement Program, mainly producing smolts for liberation to sea. In this early, pioneering stage it is apparent that salmon farming is only for those fully committed and willing and able to persevere through the formative years.

TECHNOLOGY

Normally, coho salmon require a full year of freshwater culture before adapting to a saltwater environment (25–35‰). The transfer can be accelerated by heating to advance hatching (10–12°C) and increase growth rate (12–15°C) such that a weight of about 20 g is achieved by the end of June in the first year. Alternatively, where freshwater flows over deeper salt water, creating a brackish "freshwater lens," first year transfer at 2–4 g is possible. Chinook are more adaptable, becoming smolts as underyearlings at 5–10 g; chum salmon naturally go to sea as small fry (0.3 g).

Rectangular netpens, varying in volume from 300 to 1 500 m^3, are anchored in sheltered bays or inlets. Locations of private hatcheries and marine farms are shown in Fig. 1, mostly on the east coast of the Strait of Georgia or in Alberni Inlet on the west coast of Vancouver Island. Although permitting good fish visibility, covered sheds are not favoured over the more accessible and readily handled open netpens. Anywhere from 5 to 250 such pens may span the holdings of a given farm. Knotless nylon webbing, starting at 13-mm stretched mesh for smolts and supplanted by 25-mm mesh for grow-out, will last up to 5 yr if cleaned regularly. Although automatic feeders are available, feeding of moist or dry pellets by hand is usually practiced, mainly to ensure distribution, assess appetite response, and observe the fish's behaviour. Demand feeders have yet to find general favour.

Pan-size salmon (250–350 g) can be cropped after 12–16 mo at sea, or after an additional 8–12 mo for 1–2 kg size (Fig.3). Differences in site characteristics, natural opportunity for growth acceleration, choice of species, size sorting, and feeding regimes result in considerable diversity of practice among farms. Highest survival tends to accompany those production schedules that do not involve more than one full summer at sea and that avoid high density, at all life stages.

The development of appropriate vaccines for vibriosis (a marine bacterial disease), coupled with mass application

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[1] Domsea Farms Inc., backed first by Union Carbide, and now a subsidiary of Campbell Soup Co.; estimated yearly capacity equals 700 t.

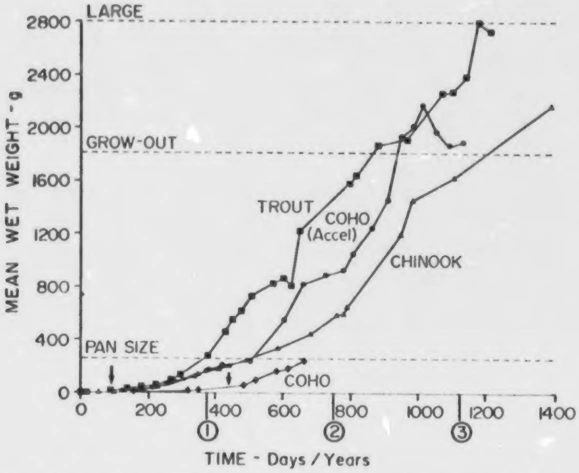

FIG. 3. Sample computer plot of growth of four stocks of fish raised at the Pacific Biological Station's experimental fishfarm. Accelerated coho (middle line) and normal coho (lower line) are shown. Zero time is that for ponding of swim-up fry and starting of feeding — within 1–2 wk of January 1 for accelerated stocks; otherwise about May 1 for normal coho and July 1 for rainbow trout. Arrows indicate sea entry for accelerated and normal coho weighing about 29 g (0.6 oz.).

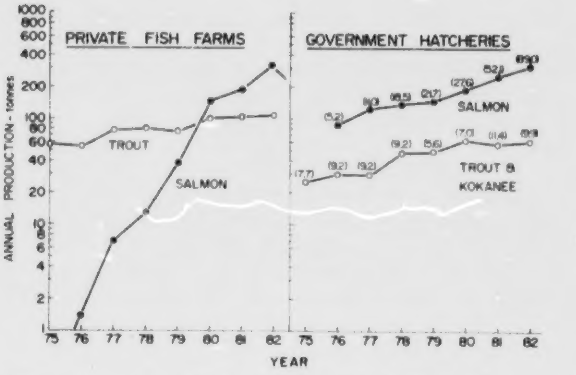

FIG. 4. Annual production of salmonids in British Columbia by private fishfarms (sales) and government hatcheries (releases). Salmon sales average 84% coho and 16% chinook. A recent figure for 1983 (not shown) indicates a farmed total of only 126 t of which 57% were coho. Numbers in parentheses are for millions of hatchery fish released. From Federal hatcheries in 1982: chum (70%), chinook (19%), coho (10%), pink (0.4%), and steelhead (0.6%); from Provincial hatcheries: trout and char (62%) and kokanee (38%). Variation in total weight of releases arises from annual differences in mean weight of fry or fingerlings as well as numbers.

techniques, has been essential for good marine survival. Other diseases (furunculosis, IHN, BKD) pose a threat, but a combination of good management and perceptive choice of antibiotics can result in 75% or better survival to pan size (Brett et al. 1978). A recent research advancement has been the economical sterilization of smolts by a controlled dose of the male sex hormone, testosterone (G. A. Hunter, pers. comm.). A small reduction in growth rate accompanies early development but maturation is surpressed and growth continues undampened, unlike that of the untreated fish. Precocious males are eliminated.

Government support includes a diagnostics service, site inspection, experimental farm demonstration, library referrals, and consultative services. However, obtaining a permit requires working through nine separate branches or departments within Federal and Provincial jurisdiction — for which time and patience must be allowed! A central agency would ease this burden.

A 2-yr intensive course in Fish Culture Technology is offered at Malaspina College, Nanaimo, B.C. Since 1981, class graduation has ranged from 12 to 14 students. To date, about 90% of these have found appropriate employment, but not all in Canada.

PRODUCTION AND PRESENT STATUS

From start-up it requires 2–3 yr for first marketable product. Since prospective farmers are strongly advised to pilot through their first crop and expand with some caution accordingly, it can easily take 4–5 yr before a first major crop is achieved. Slow returns on investment and support of high labour and feed costs make profitability[2] a tardy process. Thus, despite four permits in force by 1975, it was not until 1976 that total production even exceeded 1 t (Fig.4). By 1981 alomost 200 t were marketed, but the failure of Apex Bio-Resources Ltd. and a softening economy brought a levelling-off to what had been a projected production of two to three times this amount (Ayles and Brett 1978). However, the realignment of the industry (purchase of Apex's assets by Western Aquaculture Resources and Seaspring Salmon Farm), the present developed fish-cultural and managerial expertise, and the sorting out of the survivors (6 farms out of 12) holds more promise than in the past. Sales rose to 425 t in 1982. A survey of operators reveals a determined optimism that cannot be disregarded despite a troubled history. Factors in support of this outlook include (1) greater attention to the selection, treatment, and quality of eggs supplied and/or the development of brood stock,[3] (2) the possibility of domesticated "sea trout" (rainbow trout) diversifying production and extending the annual use of hatchery equipment, (3) slow but steady advancement in nutrition for marine stages, finishing diets, and in disease control, (4) assessment of smolt quality prior to saltwater transfer, and (5) the start of experimental breeding supported by genetic research eventually leading to domesticated strains of Pacific salmon. There is a trend now to grow larger fish than pan-size (given good survival), choosing the best time for marketing when fresh-caught wild salmon are not readily available, and diversifying through smoked and packaged products.

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[2] In 1982, British Columbia salmon farmers required $6.60/kg ($3.00/lb dressed, pan size) to achieve any margin of profit, with a survival rate of 60% or more from first-feeding fry. "Grow-out" (1.5–2 kg) fetched $7.00/kg, and "large" (2.5–3.5 kg) was $10.50/kg, if of good quality and sold between October and April (the off-season for commercial catch).

[3] A brood stock of 350–400 females should provide 1 000 000 eggs worth about $15,000 at 1982 prices.

Problems

The problems that have limited production and caused failure in the past are both biological and managerial in origin. These two cannot always be readily separated. Insensitive production schedules imposed by management have resulted in overfeeding, fouled and contaminated netpens from feces and uneaten food, excessive densities, and poorly adapted smolts; constant requirement of updated inventories at all times of the year has meant stressed fish from excessive handling, particularly in warm summer months, with consequent high mortalities. Two diseases (furunculosis and bacterial kidney disease) have not had the benefit of developed vaccines, but careful freshwater practices and initial low-density loading (nor more than 6 kg/m^3) can obviate much of the problem. Some sites have proven in time to be more precarious than others, particularly from fall blooms of an injurious phytoplankter (*Chaetoceros convolutus*) causing gill damage and death. In hindsight it is clear that this has caused the closing down of more than one Puget Sound salmon farm. Good surveillance against predator action and holes in the netting is imperative.

High netpen densities (in excess of 10–14 kg/m^3), particularly starting in early life and during warm summer months (reaching 18–20°C), have resulted in low survival. During its first 5 yr of operation, Apex Bio-Resources Ltd. did not report fry-to-market survival above 12% and only reached 21% for the 1979 stock in June 1981 — the target was 45% survival. One small, particularly successful farm has reported over 90% survival to pan size.

All salmon farms point out the slow return on investment, the high cost of feed (43¢/lb, or 95¢/kg Oregon Moist Pellets in 1982), and the need to be effective at all operating levels — culture, production, processing, marketing, and accounting. Unlike Norway, British Columbia does not have the dispersed coastal community structure (nonurban) and supporting infrastructure of regular tranportation and coastal shipping. This means its many suitable bays and inlets cannot be readily reached and serviced.

Because the combination of suitable, cool, freshwater supply in summer, along with a favourable marine site at the same location, has proven difficult to locate and service, the separation of smolt production from grow-out production must be encouraged. Until private interests can meet the potential demand, smolts should be made available from government hatcheries, as is the case in Norway.

Government Research and Development

Without a clear policy or stated priority for aquaculture research, sustained funding for salmon mariculture has been a downhill operation undoubtedly displaced in the Federal Government outlook by the overshadowing activities and expenditures of the Salmonid Enhancement Program (Fig. 5). Insufficient jobs and products have been created to catch any significant support from the Provincial purse despite a broad policy of support for mariculture.

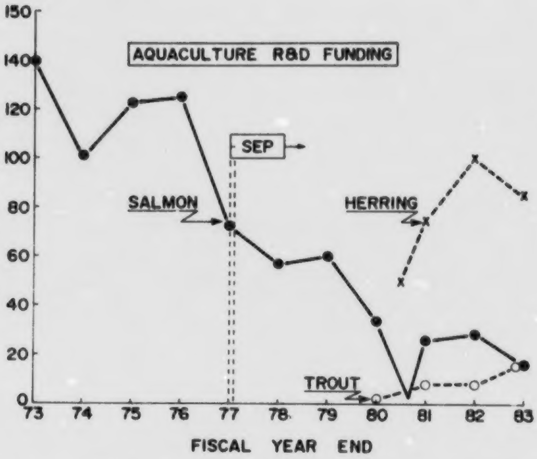

Fig. 5. Funding of research and development in finfish aquaculture by the Federal Government (salmon and herring) and the Provincial Government (rainbow trout), as conducted by the Fisheries Research Branch, Department of Fisheries and Oceans. Only monies for goods and services are shown, i.e. the program budgets (1982 $). An entry for any year refers to the fiscal year ending in that year. The start of the Salmonid Enhancement Program (SEP) is indicated.

Prospects and Potential

Given that crop yields on a sustained basis of at least 50–60% survival can be achieved, that overhead (in terms of boats, trucks, plants, and supervisory staff, etc.) is kept to an acceptable level, and that feed-to-growth ratios are optimized (both by weight[4] and dollars), the propects of profitability are reasonable (see Fralick 1980). World demand for protein is expected to increase at a rate of 10–15%/yr. Despite large commercial catches of salmon in British Columbia waters, the salmon farmer should experience advantages of market timing and provision of unexcelled quality of product. Because of major government-sponsored salmonid hatchery programs, all aspects of freshwater culture and production management can be expected to continue to improve. Projections of increased feed requirements, and assurances of quality control for hatchery production, are likely to result in supporting local feed mills,[5] thereby reducing feed costs.[6] On these grounds the prospects are good.

However, the brief and troublesome history has not resulted in banker/investor confidence, and crop insurance (if it comes) will have tight constraints. Experienced managerial staff remains in short supply. Consequently, although the essence of the old adage for successful aquaculture is in place ("seed, feed, and need"), only cautious, slow growth can be predicted.

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[4] One farm reports a favourable ratio of 1.2:1.0 using dry Abernathy pellets.

[5] Total weight of all cultured salmonids (private and public) in 1982 was approximately 600 t (Fig. 4). At an average feed ratio of 1.8:1 this would require 1 000 t of 30% moist feed annually.

[6] Fish farmers report that costs amount to 33–45% of expenditures.

Salmonid Enhancement Program

Although it does not fit our definition of private aquaculture it should be noted that the Federal Government has spent over $150 million in the past 7 yr in support of a major Salmonid Enhancement Program (SEP). In the late 1960s it became increasingly apparent that chinook, coho, and steelhead hatcheries in Washington and Oregon were beginning to contribute significant numbers of fish to West Coast fisheries, thus reflecting major improvements in fish culture technology.

In British Columbia a pilot facility was built on the Big Qualicum River (1968) and was followed by construction of major hatcheries on the Capilano River (1971) and Quinsam River (1974). Once these facilities were in place, fish culture coastwide was reassessed, and this lead to the inception of SEP in 1976. By 1983, SEP Facilities Operations comprised 27 projects, which included major hatcheries, pilot facilities, lake fertilization, and spawning channels. Production levels for 1983 were as follows:

Species	Juvenile releases	Projected catch and escapement
Coho	10.9 million	1.00 million
Chinook	22.7 million	600 thousand
Chum	146.0 million	1.76 million
Sockeye*	237.0 million	2.00 million
Pink	2.9 million	73 thousand
Steelhead	570 thousand	17 thousand
Cutthroat	37 thousand	4 thousand

*Sockeye have been enhanced by lake fertilization resulting in greatly increased natural smolt production.

The SEP Special Projects Group through its Community Economic Development Program, Public Involvement, and Small Projects Units has collectively released an additional 1.0 million juvenile salmon.

The concept behind government hatcheries is what is now called (public) salmon ranching. Juvenile salmonids are incubated and reared under artificial conditions until they reach advanced fry or smolt stage at which time they are released to ocean pasturage to feed and grow to the adult stage. When they reach harvestable size they are either cropped in various fisheries enroute to their homestream or returned to the hatchery to provide brood stock. Outstanding survival rates for hatchery produced coho,[7] together with less than optimum exploitation rates, have resulted in surplus escapement to many facilities. These surplus fish are the source of fertilized eggs for commercial fish farmers.

Production of chum salmon in SEP Japanese-style chum hatcheries has not been carried out long enough to provide a source of surplus eggs, but as these facilities reach full capacity (28 million eggs at Nitinat Hatchery, Vancouver Island) it is expected that surplus eggs of this species will become available for commercial pen rearing if desired.

It is important to note that for the current aquaculture operations much of the technology development in government hatchery facilities has been of direct benefit. Advances made in areas of incubation techniques, rearing strategies, nutrition, disease control, etc., have been adapted by the private sector.

Rainbow Trout (Steelhead trout) — *Salmo gairdneri*

SALTWATER CULTURE

Rainbow trout were the original mainstay of the Norwegian seafarms, started in the 1950s and expanded in the 1960s. However, subsequent rearing success with Atlantic salmon (*Salmo salar*) along with a superior price structure and marketability has brought a greater rate of production of salmon than of trout in that country. Of approximately 5 000 t marketed in 1978, 70% were salmon despite a tripling in the production of trout since 1971 (Edwards 1978). Expected production in 1983 is 4 000 t of trout and 16 000 t of salmon.

The nearest, naturally occurring equivalent in British Columbia is the searun steelhead trout, a racial derivative of the freshwater line. Experiments on trout growth rate in seapens have so far proven the wild type to be decidedly inferior to hatchery-spawned coho or chinook salmon. However, because it is a spring spawner and offers "crop rotation" with fall-spawning salmon, an expansion of research on saltwater rearing of rainbow trout was commenced in 1979 (Clarke 1982). Using the developed technology for inducing saltwater acclimation, domesticated lines of trout from Norway (Sunndalsora strain), England (Manx strain), and a local strain (Spring Valley) have been tested. Crosses within and between strains showed the readily available Spring Valley line to grow as well as or better than other trout strains; in addition, it was superior to salmon growth — but not in terms of survival. Careful attention to the mineral content of the diet and to brood stock selection has improved progeny survival (65% to 3 kg), sufficient to warrant testing in the private sector. Unfortunately, at present, supply of eggs from the research operation is not possible due to lack of quarantine facilities and disease-free certification. However, the possibility of a new and profitable searun trout has been added to the farmer's choice.

FRESHWATER CULTURE (PRIVATE HATCHERIES)

The 1981–82 statistics for British Columbia show that there was a cumulative total of 95 licenses issued for growing trout in raceways and ponds (Sunde 1982). Sales have generally risen from 55 t in 1975 to 110 t in 1982. Food-market sales make up 70% of production by weight, with live fingerling sales and pond fishing accounting for most of the rest. Volume of sales by the top five farmers was 82% of the total tonnage produced.

Trout imports to British Columbia from Japan and United States during the period 1974–78 were three to five times that produced within the province (Fralick 1979). There appears to be ample room for expansion if competitive pricing can be achieved.

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[7] Smolts to adult survival have averaged 15% (catch plus escapement).

FRESHWATER CULTURE (PROVINCIAL GOVERNMENT HATCHERIES)

Production of rainbow trout and kokanee salmon (*O. nerka kennerlyi*) juveniles for distribution to lakes and streams throughout the Province has continued to increase steadily — more in terms of weight than in numbers. From two hatcheries producing 5 600 000 trout and 2 100 000 kokanee in 1975, with a total weight of 25 t, output has increased to 6 600 000 trout and 3 300 000 kokanee in 1982, with a combined weight of 60 t (Fig. 4). Six Provincial hatcheries now exist, with a seventh expected to come on line in 1983 contributing to an anticipated growth in production of 10–30% over the next 5 yr.

SALMON RANCHING — A COMMENTARY

The alternative to netpen culture of salmon is the operation of *private* hatcheries for releasing smolts to sea; returning adults are subsequently harvested in the vicinity of the release site (Thorpe 1980). The advantage of such an ocean ranching strategy is the large saving in production costs. Most feeding occurs at sea, and the wasteful culture procedure of converting harvested, low-priced protein to a higher market-value protein is avoided. However, there are risks involved. The private operator counts on good ocean growth and sufficiently high survival (2–3%) to provide a profitable return despite the ravages of a sport, commercial, and native food fishery operating along the migratory route. He must therefore produce large numbers of smolts liberated from a site likely to be free from excessive public competition.

Salmon ranching occurs on the Pacific coast of Oregon (12 permits), California (1 experimental permit), and Alaska (6 fishermen's cooperatives). However, British Columbia, like Washington State, has not approved of this form of open-range aquaculture. Administratively, it is seen as one more addition to a very complex management problem already involving five species of salmon with multiple race composition coupled with an extensive program of rehabilitation — the SEP. Distinguishing hatchery stocks (for the higher exploitation rate that they can withstand) while preserving the reproductive capacity of natural runs is a formidable task. In addition, off the Oregon coast, salmon trollers are in fear of being displaced by restrictions imposed to insure good returns to the ocean-ranching investments of large, influential companies (Fishermen's News 1982). This poses a coastwide problem. In time, private ocean ranchers will no doubt demand that the fishery be managed to protect their enhanced stocks from other users. In British Columbia, exclusive harvest rights are not likely to be given. In the absence of such protection it is highly unlikely that a privately funded operation would be economically viable.

The various management tasks and issues have been presented to the Commission on Pacific Fisheries Policy (Pearse 1982). Approaches taken in the United States were not considered satisfactory models for Canadian policy development. The Commission was receptive to proposals for ocean ranching on a wider concept of enhanced natural streams (e.g. stream improvement, spawning channels, hatcheries, etc.) with habitat and stock management governed by Department of Fisheries and Oceans standards. Further, individual sites should be limited in size, with the operator able to control the catch in a terminal area while allowing for some of the enhanced fish to be taken in the traditional common-property fishery. The Commission concluded that government "policy should encourage cautious developments in ocean ranching along these lines and enable opportunities in this new field to be pursued."

In brief, the door is not closed, but with large expenditures on salmonid enhancement ($150 million in 6 yr) under review for their potential benefits, it seems unlikely that ocean ranching will surface with any vigour for some years to come.

Herring — *Clupea harengus pallasii*

BACKGROUND

Bait herring have been caught and held in live-ponds along the coast for many years. The retention period for any one catch may be so short (a few days to a few weeks) that it could hardly be graced as aquaculture. Nevertheless, the sensitivity of herring to capture and handling has necessitated refinement of techniques and development of skills. An estimated 30 sport-bait permits for live herring are operated in British Columbia.

Of greater significance to aquaculture has been the introduction of roe-on-kelp ponds in 1972. The product, which was formerly collected wild and mostly eaten by Native Peoples, consists of three to six layers of herring eggs adhering to a kelp frond. This is processed in brine and cut into strips for consumption. A particularly lucrative market for the product developed in Japan in the 1970 decade and remains good but somewhat reduced at this time. Because of a collapse of the herring resource in 1968, a tight reign has been held on issuing roe-on-kelp permits, which in 1982 only totalled 28.

A further development in the herring fishery began in 1969 when inshore fishing for mature fish was permitted, for purposes of obtaining roe for brining — another delicacy product for the Japanese market. Subsequent concern for possible damage to the spawning grounds resulted in consideration of catching herring some distance away from their spawning grounds prior to maturation. Both a research program (Brett and Solmie 1982) and two government-sponsored commercial impoundment tests (Gillis et al. 1982) have been conducted. These have been sufficiently successful that introduction of roe-herring impoundments is likely to occur with the issuing of a small number of permits by 1984 or 1985.

TECHNOLOGY — HERRING IMPOUNDMENTS

Mature herring are caught by seine and either towed in the pursed net or transferred to a live-barge for transport to the impoundment. The latter are either netted-off, shallow enclosures of up to 2 ha or a netpen (pond) capable of holding 30–50 t. One test enclosure for roe herring held about 200 t.

In the case of roe-on-kelp, freshly cut kelp fronds (*Macrocystis* sp.) are suspended in rows across the pond. Mature herring are densely packed in the ponds; the permit-holder stands by on a daily vigil until heavy spawning occurs. When the egg layers are sufficiently deep on both sides of the frond (at least three to four layers), the net is opened to release the surviving fish and the kelp carefully removed; one good frond is worth up to $50.[8]

Research on roe-herring impoundment has shown that when capture is 2–3 mo prior to full maturity, and the fish are held in netpens fouled with marine growth (e.g. colonial diatoms), spawning is delayed by 3–4 wk. This provides the operator ample time to negotiate a fair price for his fully ripe fish while guaranteeing high quality and excellent yield of roe. The high bid in a 1982 test auction was $1,150/t, equal to the best offer for gillnetted roe herring available at the time.

PRESENT STATUS

Roe-on-kelp ponds are mostly very lucrative operations ($3 million/yr wholesale from 28 operators). To date, because of the traditional cropping and use of wild roe-on-kelp by Native Peoples, a large fraction of the permits have been held by them (72%).

For roe herring, a 3-yr applied research program has shown that with adequate care, and not permitting density to exceed 8–10 kg/m^3 (when held for a 2- to 3-mo period), netpen impounding can be quite profitable (Kreiberg et al. 1982). An economic assessment revealed that benefit to cost ratios of 1.2 up to 10 can occur, depending on the source of herring (e.g. underutilized stocks), or the possible withdrawal of a fishing vessel from the existing fleet. Net annual benefit to an operator of a 100-t impoundment could amount to $50,000.

The test phase has been completed. Implementation and allocation are now being considered for diversifying the roe-herring fishery.

PROBLEMS

Permits for roe-on-kelp ponds apply to the 8 t of product permitted — not to the herring used, which currently average about 100–150 t. To get the heavy spawning desired on the kelp (and incidentally all over the net), the fish are crowded to a density of about 40–50kg/m^3. This results in stress, contact injury, and not infrequently high mortality (to 40%). Regulatory constraints are needed to prevent such losses.

For roe-herring impoundments, towing of herring in a seine net may be quite stressful, high density causes heavy losses, and too little is known about delayed spawning to make it a nonrisk factor. But in the main, when handled carefully there are no serious problems that cannot be overcome.

PROSPECTS AND POTENTIAL

On a biological and technological basis, the prospects are excellent and the potential great. Roe herring caught commercially in the past 5 yr has averaged 30 000 t. If only 10% of this were impounded, 30 permits for 100 t each could be issued. However, allocation, regulation, and fleet reduction are difficult administrative problems to preside over. A gradual increase at the rate of three to four permits per year could be expected.

Pearse (1982) stated that "the recently developed spawn-on-kelp fishery holds great promise for expansion" and "... it is now believed that sales could be expanded somewhat without depressing prices."

Sablefish – *Anoplopoma fimbria*

BACKGROUND

Sablefish, or blackcod, are widely distributed around the Pacific rim from California to Japan, being caught by longline, trawl, and trap. They spawn in deep offshore waters. Developing pelagic larvae and juveniles move inshore and provide for yearling stocks frequently found in the inlets and bays along the coast. At a weight of about 0.5–1 kg they gradually move offshore, and may be caught on occasion in large schools. Salmon fishermen, trolling with 60 lures or more, have reported finding every hook trailing a sablefish. Such reports led Kennedy (1972, 1974) to commence a study of culturing young sablefish as a potential candidate for marine aquaculture, with a view to collecting the juveniles at sea — as is practiced for some major mariculture species such as yellowtail and milkfish (caught in the sea as fry).

Sablefish turned out be be an ideal species for tank or netpen rearing — placid, tolerant, disease resistant, and easily handled. When fed on a variety of chopped fish (e.g. dogfish, herring, hake, pollock, rockfish) they grew well, adding about 150 g/fish monthly under favourable conditions, independent of size. With a preference for cooler waters (best growth at 6–8°C) they appear to offer an alternative to salmon farming, being suitable for areas along the central and northern coastal waters of British Columbia where currents and upwellings are characterized by low seasonal temperatures, particularly in summer (8–10°C). Kennedy (1972) emphasized that the target weight for culturing should be 3 kg or more, when sablefish are fairly oily and make an excellent product, namely, smoked Alaska blackcod, retailing at about $6.55/kg (1983 prices). Fishermen get $3.60/kg dressed, head off.

These promising findings for aquaculture were dampened somewhat by subsequent studies on population abundance that showed large fluctuations in year-class strength — annual availability of young was not assured (Beamish et al. 1980). In addition, no established techniques for hatching and early culture have been developed, undoubtedly a difficult task for such a small egg and delicate larval stage.

Aquaculture research on sablefish at the Pacific Biological Station was terminated in 1973 (Kennedy 1974) but is likely to be recommended in 1984.

A COMMERCIAL VENTURE

Unlike the majority of fishes, sablefish lack a swim bladder. In consequence, when brought to the surface from considerable depths they do not suffer the grotesque, destructive expansion of an air sac. Commercial catches from deep traps provide lively fish; however, these show considerable variation in size, from below the legal minimum (55 cm) on up to 70 cm or more. The availability of legal-sized, small sablefish of comparatively low market value struck Mr. F. Strickland, a blackcod fisherman, as suitable

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[8] In California the retail price ranges from $18 to $44 (U.S.) /kg depending on the quality.

TABLE 4. Finfish aquaculture production in 1982 by private operators. Roe-on-kelp production is average of last 3 yr (*seasonal; **estimated; ***not operating).

Species	Permit (no.)	Active (no.)	Employ (no.)	Production (t)	Value ($000)
Pacific salmon	12	6	35	425	2,100
Coho	(12)	(6)	—	84%	—
Chinook	(12)	(6)	—	16%	—
Chum	(12)	(1)	—	(1%)	—
Rainbow trout					
Freshwater	95	5+	40**	79	435
Saltwater	1	1	1	0	0
Herring					
Bait	30**	5+	15*	70	75**
Roe-on-kelp	28	28	56*	196	3,000
Sablefish	1	1	5***	0	0

material for culturing to a larger, more marketable size (3–5 kg). His consultations and accounting provided convincing evidence that a commercial venture on a sufficient scale of magnitude (100 000 fish) could be profitable. Westerly Fish Farms Ltd. was launched. The initial choice of location was Stickland's home-port of Butedale on the central coast. The imaginative new project created considerable interest in both the Federal and Provincial governments. Because of employment potential and the closing down of a large pulpmill at Ocean Falls in the same general vicinity, Stickland moved his culture site to Cousins Inlet, and negotiated a supporting financial contribution from the Federal Government.[9]

The plan was simple. Suitable, small-size sablefish would be selected from traps on the fishing grounds and transported by fishboat or barge to netpens anchored in well-flushed waters of Cousins Inlet. Low-priced groundfish (hake, dogfish, rockfish, etc.) would be prepared as feed for the voracious young fish. Within 1–2 yr of start-up, market flow of larger fish suitable for smoking would begin.

Between March and July of 1982 some 25 000 sablefish were caught and hauled to the netpens (S. McFarlane, pers. comm.). By the end of August, 50% were dead and very few if any were expected to reach market (W. A. Kennedy, pers. comm.). From the start, the project was fraught with problems: transportation, site suitability (surface temperatures rose above 10°C; heavy runoff caused low salinity), faulty netpen construction, periodic density stress, feeding problems, and disease from infected wounds. Aside from some useful insights on transportation and handling (R. H. McIlwane, pers. comm.), there appears little hope of rescuing substantial information.

PROSPECTS AND POTENTIAL

West coast stocks of blackcod are considered to be at a level of maximum exploitation (total allowable catch = approximately 3 500 t). Demand is on the increase; a favourable market exists. The development of sablefish aquaculture is therefore timely.

The basic premises of sablefish culture as developed and expounded by Kennedy (1972), and the use of small, legal-sized fish from deep traps as proposed by Westerley Fish Farms, still stand as viable approaches to sablefish mariculture. The essential first steps of conducting a pilot test, both of the transportation and culture systems, as well as assessing the selected site, remain as confirmed preliminary imperatives.

Sablefish aquaculture has had a troublesome setback. However, at least three serious enquiries by interested parties are under consideration. The potential remains; the prospects have been shaken, but the long-run outlook of profitability is as inviting as ever.

Vertebrate Summary

By 1982, 12 salmon farming permits had been issued. Only one, possibly two, could claim profitability. Due to the failure of the one large farm in an otherwise small cottage industry, production has not exceeded about 400 t/yr (Table 4). Only a gradual increase is forecast.

Without vaccines for controlling vibriosis, salmon farming on the Pacific coast would be virtually impossible. As it is, the risks are high enough, and only strict adherence to the best fish culture practices provides enough grow-out fish for potential profit in the marketplace. All farmers agree that the biological and technological aspects are sufficiently in place to make salmon farming a viable business, yet to date, more have failed than survived.

While there is plenty of room for improving the various stocks and culture practices, particularly through improved marine diets (grow-out and brood stock), density control, disease reduction, and stock domestication, *failure to reach profitability has primarily meant failure to achieve high survival of good quality fish*. This can be rectified.

Diversification of farmed salmonid species (coho and chinook) by the inclusion of "sea-run" domesticated rainbow trout is a promising new development from research.

The alternative of ocean-ranching for salmon has yet to be approved in British Columbia. The complex problem of managing the large natural and enhanced salmon resources presently precludes the addition of another complicating fishery. However, a broadly based salmon enhancement practice, with sharing of public and private interests, has been proposed in a 1982 commission report.

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[9] A contribution arrangement with the National Research Council of Canada under the Program for Industry Laboratory Projects (PILP).

Impounding of herring for roe-on-kelp production is a prospering $3 million/yr business for the present 28 permit holders. Research into impounding roe herring prior to maturation and away from spawning grounds has proven both feasible and economically favourable. Expansion along these lines is anticipated but allocation problems in a highly restricted fishery militate against rapid expansion.

The first commercial effort to raise sablefish from a small fish of legal size to a higher valued, large fish has been a dismal failure at the basic fish culture level. However, the prospects remain good but unproven.

To add it all up, so far only three species of fish (coho, chinook, and herring) have been successful candidates for mariculture along British Columbia's coast. Their suitability has been recognized and some of their potential experienced. Yet much remains for their private culture to become firmly and profitably established. Sea-run rainbow trout, chum salmon, and sablefish are likely to be next on the successful list, with only distant prospects for pink salmon and sockeye salmon. Still further down the line, the egg-guarding lingcod and viviparous pile perch merit research attention. White sturgeon can also be included.

On the side of government, what constructive recommendations can be made? The following are submitted:

(1) Experimental fishfarms involving production through to marketing should be kept moving at the forefront of the industry.

(2) Accurate production records and thorough-going annual reports including fish losses should be submitted and analysed for problems and trends — to help the industry and provide incentive rewards (e.g. more seed) for the successful farmer.

(3) Greater effort is needed to make chinook salmon eggs available throughout the British Columbia coast.

(4) Provision for the supply of smolts is required, to the extent that, and as long as, the demand exceeds supply by any private producers.

(5) It is desirable to have Canadian manufacture and distribution of first-class feeds, suitable to the different life stages and environmental conditions typical of coastal farms. This would involve coastal centres for storage and refrigeration and include inspection of feed quality.

CONCLUDING REMARKS

The report of the 1973 Aquaculture Conference was entitled: Aquaculture in Canada, the Practice and the Promise. The phrase, "the Practice and the Promise," is as appropriate today as it was in 1973. There is promise for aquaculture in British Columbia. The coastal waters have ideal conditions and offer great potential for an extensive mariculture industry based on a variety of species. However, to date, the practice has not been encouraging. Production from the one cultured invertebrate species has declined in recent years and there have been several major failures in vertebrate culture. We have discussed some of the reasons why the promise of aquaculture has not been achieved in British Columbia.

In spite of limited production from aquaculture there is reason to be optimistic about the future of mariculture in British Columbia. It must be recognized that an aquaculture industry will not develop overnight and it is not a "get rich" operation; it will evolve over a number of years. Mariculture is often compared with agriculture but it requires a higher degree of technology than agriculture. Mariculture is many years behind the advanced state of technological development in agriculture and it will take time to solve the problems facing it. Much research must be undertaken in a variety of fields from culturing to marketing to solve these problems and establish a viable aquaculture industry. Above all there must be a firm commitment to this research until work is brought to fruition and the industry is established.

Development of the industry may be hastened with research that leads to breakthroughs in technology. Developments in such fields as genetics, disease control, improved hatchery techniques, better diets, etc., could produce results that would hasten advancement.

Establishment of a pilot plant facility, where results of reseach studies could be developed and brought into full-scale commercial production, would hasten advancement of aquaculture in the Province.

Products from an aquaculture industry can be expected to find ready acceptance in a marketplace that is continually expanding as population expands. This means that a major effort must be made by the industry to improve the quality of the product. Initially, mariculture will produce high-priced (luxury) products because of the present specialty market; consequently, every effort must be made to insure that the consumer receives top-quality food products.

Finally, it is very apparent that only the mariculturist who can master every step from the initial stages of procuring juveniles to the final product in the marketplace will succeed. This breed of aquaculture businessman, supported by a full range of adequate research and technical support together with a policy of stability and encouragement by Federal and Provincial agencies, will surely be able to achieve the potential of coastal mariculture that awaits the prospective British Columbia entrepeneur.

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AN OVERVIEW OF AQUACULTURE IN CENTRAL CANADA

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ABSTRACT

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Government fish hatchery systems and live release programs are a major component of fisheries management in all four provinces of central Canada. Average annual production of some 16 species is approximately 217.5 million fish. Private sector aquaculture produces annually an estimated 482.6 tonnes (t) of rainbow trout for domestic markets, plus live sales of rainbow and brook trout and a few blackbass for stocking recreational waters. No appreciable growth in the fish farming industry has occurred recently and, without innovative biotechnology, diversity of products and market promotion, an early major expansion of central Canadian aquaculture is questionable. While a number of trout farms (some small and mostly family operated) realize significant profits over investment, the industry as a whole faces severe market competition from imports of foreign trout, mostly from the USA, which make up over 50% of domestic trout sales in central Canada.

In the absence of speculative industrial investment in the development of aquatic food production in central Canada, the future direction of aquaculture in these provinces will depend largely on the extent to which federal and provincial governments may elect to extend the precedent of costly agriculture subsidization programs to the embryonic aquaculture industry in the form of research, development and price support programs. It will no doubt be possible to grow numerous native and alien aquacultural products at north temperate latitudes using conventional and innovative husbandry, but favourable markets and long-term cost benefits are less certain if not precarious.

This paper focuses on the status of aquaculture in the provinces of Ontario, Manitoba, Saskatchewan, and Alberta, and identifies key issues relative especially to the future of private sector aquaculture in central Canada.

HISTORICAL PERSPECTIVE

Fish have been cultured in Ontario since 1865, in Manitoba since 1893, in Alberta since 1914, and in Saskatchewan since 1915 under government or private auspices. By 1890, the ingenuity of early fish culturists had devised techniques for the artificial spawning, ova incubation, and early rearing of some 12 fish species. Since 1890, an additional 11 species have been cultured for live release, as food, or for experimental purposes (Table 1). For a more complete account of the historical aspects of government and private aquaculture in central Canada, the reader is referred to MacCrimmon et al. (1974).

Government fish culture programs in the central Canadian provinces have continued, since their onset, to focus on the live release of sport and food fishes into natural waters for anticipatory recovery by recreational and commercial fishermen. With the exception of the salmonid fishes, only limited effort has yet been made to rear most native species beyond the eyed-egg, fry, or fingerling stage before release into natural or impounded waters. This phenomenon would seem to be partially a reflection of government policies which, historically, have recognized the greater political advantage of fish numbers over size in hatchery release programs.

Recent advances in government aquaculture in central Canada have focused principally on salmonid fishes because of growing public pressures for put-take recreational angling and growing evidences of better angling recoveries from live releases of larger charr and trout (Fry and Budd 1958; Millard and MacCrimmon 1972; Fraser 1976, 1978).

Techniques presently used for the pond culture of centrarchid and cyprinid fishes, and for the jar culture of coregonid and percid fishes, are essentially those developed and proven by pioneer fish culturists (Table 1). Significant innovations since that time include modest successes with pond rearing and live release of jar-incubated juvenile walleye in

Table 1. Fish species cultured in the hatcheries of central Canada.

Prior to 1890	Additions since 1890
Atlantic salmon (*Salmo salar*)	Cisco (*C. artedii*)
Lake trout (*Salvelinus namaycush*)[a]	Kokanee (*O. nerka*)[a]
Whitefish (*Coregonus clupeaformis*)[a]	Brown trout (*Salmo trutta*)[a]
Salmonid hybrid (*S. salar* × *S. fontinalis*)[b]	Cutthroat trout (*Salmo clarki*)[a]
Arctic charr* (*Salvelinus alpinus*)[a]	Perch (*Perca flavescens*)
Brook trout (*Salvelinus fontinalis*)[a]	Maskinonge (*Esox masquinongy*)[a]
Blackbass (*Micropterus dolomieui*)[a]	Coho salmon (*O. kisutch*)[a]
Chinook salmon (*Oncorhynchus tshawytscha*)[a]	Pink salmon (*O. gorbuscha*)
Walleye (*Stizostedion vitreum vitreum*)[a]	Splake (*S. fontinalis* × *S. namaycush*)[a]
Carp (*Cyprinus carpio*)[b]	Grayling (*Thymallus arcticus*)[a]
Rainbow trout (*Salmo gairdneri*)[a,b]	Cherry salmon (*O. masou*)
Goldfish (*Carassius auratus*)[b]	

[a] Presently cultured in central Canada.

[b] Private auspices only.

*The spelling differs from that (char) used in *A List of Common and Scientific Names of Fishes from the United States and Canada*, by the American Fisheries Society, and is preferred by the author.

the prairie provinces, and maskinonge and whitefish in Ontario to advanced fingerling size. Until such time as enhancement benefits to commercial fisheries from releases of ova, sac-fry or juvenile whitefish, cisco, walleye or perch are demonstrated, a return to the historic volume production of these commercial species (Lapworth 1956; Dymond 1956; Christie 1963; Cucin and Regier 1965) is unlikely in the Great Lakes basin despite evidences of successful whitefish introductions in the prairie provinces (Rawson 1946; Scott and Crossman 1973). Little recent attention has been given to the pond production or live release of presently less-preferred warmwater sportfishes.

Efforts to enhance natural fisheries with alien species have resulted in importations into all provinces of central Canada, especially Ontario where some 10 species have been imported on an experimental or practical basis since the first introductions of Pacific salmon in 1874 (MacCrimmon 1977). Despite the controversial nature of exotic species introductions, Ontario presently releases coho and chinook salmon on a put–take basis in Lake Ontario, while pink salmon have become self-sustaining following modest releases in Great Lakes waters in 1956 (Kwain 1978). With the exception of the carp which is now locally abundant in all four provinces (McCrimmon 1968), and western extensions of the range of the blackbass (Robbins and MacCrimmon 1974), the principal exotics are coldwater fishes. The rainbow trout has evolved as a significant sport fish in the hatchery programs of all provinces, with a resurgence of government interest in the culture and release of the brown trout. The rainbow trout, a mainstay of both the public sport fishery and private sector fish farming, was first cultured in Ontario in 1887, Alberta in 1919, Saskatchewan in 1924, and Manitoba in 1937 (MacCrimmon 1971).

Fish hybridization occurred first in Ontario with the experimental crossing of lake trout and Atlantic salmon in 1868 (MacCrimmon 1977). Canadian interest in the breeding of splake was initiated in Ontario in 1917, and revitalized in Alberta in 1946. Beginning in 1950, the Ontario splake program has led to extensive releases into the waters of Lake Huron and several inland lakes (Budd 1957; Berst and Spangler 1972; Spangler and Berst 1976). The species is now cultured for live release by government agencies in Manitoba and Saskatchewan as well, and its commercial potential is of increasing interest to private sector fish farmers (Watson et al. 1983).

STATUS OF GOVERNMENT FISH PRODUCTION

Based on information provided by federal and provincial agencies, it is estimated that some 217.5 million fish weighing 356.6 t are being produced and distributed annually from 21 stations (Table 2). Of this production, salmonids (trout, charr, salmon, and grayling) make up 70.2% by weight, but only 5.8% by numbers, as the production of some 205 million walleye, whitefish, maskinonge and blackbass continue to be released principally as ova or fry. The Department of Fisheries and Oceans, in cooperation with the Province of Manitoba, is investigating the use of ponds for summer rearing of walleye prior to release into natural waters. Ontario has successfully cultured year-old whitefish. This is not yet a standard hatchery practice but follows the long-established procedure of the Ontario government for blackbass and maskinonge culture in enriched ponds (MacKay 1963; Scott and Crossman 1973).

Average annual salmonid production from government hatcheries in recent years has exceeded 12.6 million fish with an estimated weight of 250.5 t. Rainbow trout make up the bulk of the production by numbers (53.1%) followed by lake trout (19.79%) and brook trout (16.6%). Other species of salmonids under propagation, including the hybrid splake, make up only 10.6% of the total numbers produced for distribution to fishing waters. Salmonids are planted in ponds, reservoirs, and natural waters principally as fingerling, yearling, or 2-year-old fish.

Ontario

The Ontario Ministry of Natural Resources, as part of its mandate to manage recreational and commercial fisheries, maintains a substantial fish hatchery and live release program. Present policy favours the utilization of limited hatchery space for the rehabilitation of natural fisheries rather than the creation of artificial fishing opportunities. Thus, there exists the opportunity for private sector aquaculture to provide, under contract with the Ministry, catchable rainbow and brook trout for provincial fishing areas. In future, the Ministry may also rely on the private sector for production of fish to use in "put-and-delayed-take" fisheries, dependent on the development of appropriate quality control guidelines for fish to be purchased (Pope, Castledine, personal communications).

Over the past few years, distribution from Ontario fish culture stations has averaged around 13.5 million fish or an annual production of about 138 t (Table 2). For future expansion, an addition to the North Bay Fish Culture Station (Nipissing County) is under construction, and property has been purchased at Harwood for a new hatchery which is at the design stage.

Manitoba

The hatchery system of the Manitoba Department of Natural Resources is an important part of their fisheries management program, especially in view of increasing emphasis on rehabilitation and enhancement. Stocking is viewed as a means to increase angling opportunities and commercial production. Fish releases are used to rehabilitate depleted populations, to introduce self-sustaining populations to new water bodies, to create put–take fisheries in areas of high demand to alleviate fishing pressure on natural stocks, and to provide a variety of new fishing opportunities through introduction of nonnative species, especially rainbow and brown trout (Mackling, personal communication).

Recently, annual sport fish distribution has amounted to 610 800 salmonids and 4.45 million walleye fry (Table 2). Mean numbers of fry stocked to enhance commercial fisheries has been 86.2 million whitefish and 95.6 million walleye. Government hatcheries have a production capacity of 190 million whitefish eggs and 300 million walleye eggs, but production is usually less. Conversion of the Dauphin River Hatchery in 1983 from a whitefish to a walleye hatchery will increase walleye carrying capacity in government hatcheries by 230 million eggs. It is also planned to replace the Duck Bay Hatchery (Lake Winnipegosis) which was destroyed by

TABLE 2. Recent statistics from Government Fish Culture Stations in central Canada.

Province	Number of fish culture stations	Species reared	Average number distributed annually (× 10^3)	Average annual production (tonnes)	Capital investment ($)	Annual operating cost ($)	Water source and flow (L/min)
Ontario	14	trout, brook	1 579.4	40.3	unk.	2.10 M	ground (spring/wells): 83 110 (9)[b] surface (lakes): 40 365 (5)
		rainbow	1 300.9	37.3			
		lake	1 926.5	32.1			
		splake	683.8	24.2			
		aurora	14.3	0.2			
		salmon, chinook	99.4	0.1			
		coho	296.6	3.6			
		bass, smallmouth	139.6	0.2			
		maskinonge	1 177.8	0.1			
		walleye	6 182.4	0.1			
		total, all species	13 490.7	138.2			
Manitoba — provincial	4 (+ one planned)	trout, brook	137.2	45.5 (max.)	3.7 M	0.60 M	ground (wells): 6 818.9 (1) surface (river/lake): (4)
		rainbow	163.0				
		lake	223.9				
		splake	49.4				
		brown	37.3				
		whitefish	86 200.0				
		walleye	100 050.0				
		total, all species	186 860.8				
— federal	1 (research)	trout, brook	78.4		2.5 M	0.23 M	ground
		rainbow					
		Arctic charr	16.2				
		total, all species	95.6				
Saskatchewan	1	trout, brook	94.7		5.0 M	0.25 M	ground (deepwells) surface (lake)
		rainbow	296.2				
		lake	72.4				
		splake	19.5				
		brown	15.6				
		Salmon, kokanee	3.5				
		Arctic grayling	8.8				
		whitefish	3 750.4				
		walleye	7 425.0				
		total, all species	11 686.1				
Alberta	1 (+2 brood stations) (+ walleye/trout station: proposed rainbow rearing: 1983/84)	trout, brook	266.7		—	—	ground (wells)
		rainbow	4 882.7				
		lake	246.3				
		brown	8.2				
		cutthroat	93.6				
		total, all species	5 497.5	55.1			
Central Canada	21	trout/charr	12 207.2	246.6[a]			ground: (13) surface: (10)
		Pacific salmon	399.5	3.7[a]			
		Arctic grayling	8.8	0.2[a]			
		smallmouth bass	139.6	0.2			
		maskinonge	1 177.8	0.1			
		whitefish fry	89 950.4	1.4[a]			
		walleye fry	113 657.4	1.8[a]			
		total, all species	217 540.7	356.6			

[a] Estimated.

[b] Number of hatcheries, some have both ground and surfaces sources.

fire in 1982. Present total annual hatchery capacity for salmonids is 45 450 kg, through the rearing of any combination of juvenile and older fish. Rearing trout to "preferred table size" as 2-year-olds in provincial hatcheries costs $1.55/fish at Grand Rapids Hatchery and $2.60/fish at the Whiteshell, including annual operating and salary costs but not capital assets (O'Connor, personal communication).

At present, there is no direct private sector participation in the government hatchery system or in fish releases to public waters. The feasibility of rearing trout species in prairie pothole lakes for sport fish stocking is being investigated, however, and the private industry could have a future role in such a program if it is ever implemented.

The Rockwood Experimental Fish Hatchery (65 km north of Winnipeg), operated by the federal government, is presently rearing various strains of salmonids for research, some stocking for extensive (lake) aquaculture studies, and a small amount of sport fish stocking (Papst, personal communication).

Saskatchewan

To keep pace with the growing needs of active anglers, which are expected to increase by 40% within the next decade, the Department of Tourism and Renewable Resources foresees a definite requirement for intensive effort in fish culture. This involves both a lakeside rearing pond program for native species and a greater development of the stocked trout program to perhaps twice its present capacity. Over recent years, salmonid production has averaged slightly over 0.5 million fish (Table 2) including small numbers of kokanee and grayling (McLeod, Swanson, personal communications).

At present, Saskatchewan is updating its multispecies hatchery at Fort Qu'Appelle at a cost of $2.4 million, but it will not involve a major increase in hatchery production. As it is stated that purchase of trout from the private sector would be considered as the need arose, this may provide profitable opportunities for fish farmers in the future.

Alberta

The Department of Energy and Natural Resources considers the management of wild stocks and the protection of their habitat of paramount importance and these stocks will be relied on to provide the majority of fish required for recreational fishing. However, trout releases to small lakes where natural reproduction does not occur provide a large number of recreational man-days of fishing in the province and the government is currently expanding its hatchery and rearing facilities to satisfy an increased demand for trout fishing especially near centres of population (Sparrow, personal communication).

In recent years, an average of nearly 5.5 million trout, close to 55.1 t in weight, have been distributed annually to public waters (Table 2). Beginning in the 1983 fiscal year, it is intended to raise 200 000 catchable rainbow trout at the Sundance Rearing Station, a recently purchased facility, using waste heat effluent to increase winter hatchery production. Minor purchases of trout from the private sector are made occasionally to make up shortfalls in production, but it is anticipated that fish farmers will play an increased role in providing trout for stocking public waters. It is contrary to government policy to supply trout to fish farmers, although provision has been approved to provide the private sector with up to 2 million eggs annually if required (McFadden, personal communication).

Although coolwater fishes are not presently reared in government hatcheries, an enhancement program is underway to restore walleye populations to near former levels, and a combined walleye and trout hatchery is proposed at Cold Lake.

STATUS OF PRIVATE SECTOR AQUACULTURE

The commercial and home production of aquaculture products in central Canada, with the exception of a comparatively small number of brook trout and fewer blackbass in Ontario, is limited essentially to rainbow trout. No competent estimate of either total quantity or value of fish marketed can really be made because of deficiencies in the data base presently available. Reliable estimates are further confounded by differences in survey methods and data grouping for analyses (MacCrimmon et al. 1974; Canada Department of Fisheries and Oceans 1980; Graham 1983).

The most reliable component of the information base on production by the private sector is that reporting on fish sold on domestic markets as fresh and frozen food. On the basis of data provided by federal and provincial agencies, the annual production of domestic trout in central Canada is estimated by the present study at 482.5 t in 1982. This constitutes about 40% of the present annual Canadian aquaculture production of all salmonid fishes for domestic food markets. If sales of live fish are included, the value of all fish produced by central Canadian fish farmers in 1982 is estimated at $4.2 million. This would seem to be a conservative estimate. Of the central Canadian provinces, using dollar values, some 73.3% of the commercial sales of fish occurred in Ontario, 12.8% in Alberta, 12.5% in Saskatchewan, and 2.4% in Manitoba. There are no confirmed data to indicate that private sector fish production in central Canada has increased substantially over the past 3–5 years.

The annual quantity of fish raised privately for personal home consumption (principally by pond owners) is unknown. Licences or permits are issued for this purpose in the prairie provinces for negligible cost for statistical purposes. It is estimated that noncommercial operations in the prairie provinces yield some 115–120 t of rainbow trout annually (Canada Department of Fisheries and Oceans 1982). No comparable data are available for Ontario, although the total harvest of trout for personal recreation and food from the thousands of private ponds is no doubt substantial.

Despite lingering and sporadic interest in the commercial culture and sale of other indigenous fish species for recreation, food, or bait fish; no strongly progressive steps have yet been taken to identify those species with the best potentials for profitable aquaculture. However, some bait fish, principally catastomids in Ontario, are now cultured commercially on a small scale. Neither the amount or value of imports of ornamental fishes into central Canada nor the extent of the culture of these aquarium species are presently documented.

Ontario

The aquaculture industry has grown significantly in Ontario over the past 10–15 years but is constrained because of limited water supplies of suitable quantity and quality for large-scale production (Pope, personal communication). The large majority of licenced fish farmers in Ontario are small farm operators, although there is a tendency to expand commercial operations. Several fishing clubs and fish farms combine recreational angling or pay fishing with domestic fish production. About 30 commercial fish farm operations in Ontario derive a reasonable income from aquaculture and probably represent more than 90% of the productive capacity of the industry (Blum 1982; Castledine, personal communication). Nearly half of the total Ontario production of trout by the private sector is provided by some six farmers (Joyner and Beamish 1983). Rainbow trout is the principal species reared, but some farms also raise brook trout and/or blackbass. In 1977, sales were 91.1% rainbow, 8.7% brook, and 0.2% bass by number (Castledine, personal communication). It is not known how many people raise fish for their own use, or the quantities harvested.

The industry is represented by the Ontario Trout Farmers' Association which promotes the use of homegrown trout for human consumption and recreation, and distributes information on fish farming to the general public, and intercedes on the industry's behalf in deliberations with government agencies. Membership is not compulsory, although most major commercial operators are members (Blum 1982). There is evidence that Ontario fish farmers may not yet have the confidence of the fish brokers presently enjoyed by foreign suppliers of domestic trout (Ontario Energy Corporation 1981), i.e. stability of supply, quality, and price.

The total estimated value of fish sold (for stocking and food) in Ontario is approximately $3.0 million annually. Domestic sales (fresh or frozen trout) average about 350 000 kg, valued at some $1.4 million (average of $4.00/kg). These sales are predominately of 250–350-g size rainbow trout. Live fish sales include the local marketing of rainbow trout (250–350 g) at markets and to restaurants at $2.00 to $3.00 per fish; ova, fry and fingerling trout exchanged within the industry; and plantings of trout fingerlings, older trout, and some bass to public and private angling waters (Castledine, personal communcation). Although a few white sucker (*Catostomus commersoni*) are cultured and reared for commercial sale in growout ponds at several locations in Ontario (Aitkens 1983; Castledine, personal communication), live bait marketed in the Province continues to be essentially from natural waters.

Ontario retail outlet prices for homegrown fresh rainbow trout fluctuate between about $4.40 and $7.00 per kg, which is attributed, in part, to competition among producers which, it is hoped, can be eleviated by a recent cooperative approach to wholesale marketing. Imported trout, principally from Idaho at present, compete extensively with the locally produced product because of a reputation for stability in availability, quality, and competitive price (Castledine, personal communication). However, a processing and marketing cooperative has been established and seems to be operating successfully (Byrne, personal communication).

Aquaculture equipment and commercial trout rations are available from Ontario manufacturers. Feed sales are approximately $500,000 to fish farmers, plus some $150,000 to government salmonid hatcheries (Castledine, personal communication). An estimated 950 t of fish feed are sold annually by feed manufacturers in Ontario (Preston, personal communication). Overall, feed, equipment, and other retail sales associated with the domestic fish farming industry are approximately $4.0 million per year (Castledine, personal communication).

Manitoba

Extensive aquaculture (i.e. pothole farming of rainbow trout) has been practised in Manitoba since 1968, but still has inherent financial risks. It is dominated by owners who view trout farming as a hobby (Mackling, personal communication). Some 30–40 farmers are licensed to sell dressed trout for human consumption, and 300–350 farmers are issued annual permits for personal use of trout produced. There has been no significant expansion in the number of fish farmers since the mid-1970s. No owner or investor is believed to rely on a fish farming as a principal source of income (O'Connor, personal communication).

There are only two private operations in the province with rearing and/or holding facilities, and both provide certified rainbow trout. One imports eyed-ova for fingerling sales (600 000 eggs imported in 1982 for the 1983 market). The other is the Manitoba Rainbow Trout Farmers' Association which acts as a broker for imported fingerlings from South Dakota and Nebraska (430 000 were imported for resale in 1982). Most trout farmers purchase fingerlings from the Trout Farmers' Association and, since only members can buy from the Association, its membership includes almost all private and commercial trout farmers in Manitoba (O'Connor, personal communication).

Rainbow fingerlings of 10 cm are usually sold for about 20¢ each and only rainbow trout are available for fish culture operations. There is no indication of total annual fingerling sales, or the revenue generated. The other fish farmers rear trout in prairie lakes or ponds for domestic sale or personal use. No fish farmer is presently offering pay angling.

Quantities of rainbow trout harvested for commercial sale are unknown. In the late 1970s, some 25 t of trout were reported to be harvested annually by commercial fish farmers. Present harvests are not believed to be dramatically higher with gross sales in 1982 estimated at < $100,000 (O'Connor, personal communication). Average size of fish produced was about 475 g, with sale price varying from $2.20 to $2.75/kg round weight. The price for dressed trout averaged about $3.00/kg ($2.10–$4.40/kg).

The majority of trout produced are sold fresh to private consumers with few fish being sold through food stores. No significant local secondary industries are presently associated with the trout farming industry and, in fact, Victor Fox Food Limited, formerly a major Canadian supplier of trout feed for prairie fish farmers, reports (personal communication) that it has presently discontinued the manufacture and distribution of fish food because of the low demand for commercial trout rations.

Saskatchewan

Fish farming in Saskatchewan has developed largely without government assistance or involvement, but now seems to have levelled off with about 2 000 private and 50 commercial trout farmers licensed annually. The majority of fish farmers, therefore, are hobbyists who raise fish strictly for their own use under a private aquaculture licence, and it is unlikely that this segment of the industry will show much increase over the next few years. Of the commercial licensees, five supply live trout and the remainder market fish for domestic sale. None sell recreational angling. It is doubtful if aquaculture is the primary source of income for any of the licensees (Orr, Swanson, personal communication).

Two fish farming organizations, the North Saskatchewan Rainbow Trout Farmers' Association and the South Saskatchewan Rainbow Trout Farmers Ltd., represent the industry. Their primary function is to facilitate the distribution of trout fingerlings to members and to circulate fish farming information.

It is estimated that the total value of commercial trout production in 1982 (live and domestic sales) was $524,000. Rainbow trout is the only species reared by fish farmers in Saskatchewan. Approximately 675 000 fingerlings, ranging in size from <8 to >15 cm (51%, 10–13 cm in length) were sold in 1982, with a total value of about $220,000, to private and commercial fish farmers. Trout fingerling distributors also sell gill nets and trout food to their customers (Swanson, personal communication).

In the fall and early winter of 1982, an estimated 73.6 t of trout were harvested by commercial fish farmers at an estimated value of about $304,000. The average price is $4.40/kg with most fish being sold dressed to local purchasers. Comparatively few fish are sold to retail outlets so an accurate estimate of price is not available. Some imported trout, principally from Idaho, are sold in major food chains but these imports probably do not provide a great deal of competition as most people prefer local fresh fish when available (Swanson, personal communication).

The current value of fish farming to the provincial economy is estimated at between $0.75 to $1.0 million. One Saskatchewan feed manufacturer, Pay Way Feeds, is marketing its own brand of trout food but amount sold makes up under 1% of total sales of all agricultural feeds (Gumprich, personal communication). Agricultural suppliers also sell a small amount of copper sulphate each year for algae treatment in fish ponds.

Alberta

Aquaculture in Alberta is primarily the extensive culture of rainbow trout by hobbyists, with very specialized opportunities by only a few commercial operators. Of about 12 serious attempts to establish viable commercial trout rearing operations in Alberta, only about half have proceeded after serious consideration of environmental constraints or market capabilities. Only one has been financially successful with a dependency on the importation of low cost fingerling and yearling trout (5–15 cm size) from Washington State (Paetz, personal communication).

At present, of those holding commercial game fish farm licenses, some 40 rear fish for domestic sales, 4 for fingerling sales, and 10 offer recreational pay fishing. In addition, about 1 500 private fish farmers are licensed to rear trout for their own use. Numbers and types of licenses issued have remained relatively constant and appear to be dependent on the availability of trout for spring plantings. Licensed game fish farmers are permitted to rear rainbow, cutthroat, brown and brook trout, and kokanee salmon but, at present, rainbow trout is the only species available. To date, any attempts at forming a fish farming association have failed (Chamberlain 1981; McFadden, personal communication).

Total value of commercial fish farming products (live sales and domestic markets) is estimated at $531,000. Spring sales of about 400 000 live fingerlings (av. size 20 cm) for stocking purposes are valued at some $400,000. Approximately 80% of the fish farmers purchase certified stock (largely between 20 and 30 cm in length) from the one source. The other three commercial operators offering live sale gain only supplemental incomes from fish farming (McFadden, personal communication).

About 34 t of rainbow trout, valued at $131,100, are harvested for domestic sale each year. The majority of these fish are sold directly to the consumer since no single fish farm operation produces enough fish for wholesaling to supermarkets on a regular basis. About 10% of marketed trout are sold to wholesale outlets. Dressed rainbow trout (average size: 340 g) sell at about $3.85/kg wholesale. Retail market prices range from $5.72 to $8.78/kg. Rainbow trout mainly from the USA and some from Japan are sold in the supermarkets, but retailers indicate that Alberta grown trout could be sold easily if consistent suppliers were available (McFadden, personal communication).

Present value of commercial fish farming to the provincial economy is not great, but the importance of put-take recreational fisheries is recognized. With the exception of a single feed supplier who produces a small amount of supplemental feed for pond-reared trout, and the importers and producers of fingerling fish, trout farming in Alberta has stimulated no support industries.

FOREIGN IMPORTS OF DOMESTIC AQUACULTURAL PRODUCTS

Recent annual imports of fresh or frozen trout to Canadian markets have averaged 1 233.6 t with a wholesale value of about $3.9 million (Table 3). Of this quantity, direct imports into Ontario make up about 45%, while Alberta and Manitoba receive about 2% each. The extent to which these imports, and those entering the other provinces, are redistributed by fish brokers and chain stores within the Canadian market is not known. However, it is estimated that about two-thirds of the trout sold in Ontario are imported fish, principally from Idaho (Ontario Energy Corporation 1981). Available records indicate that only rainbow trout are imported into Canada for domestic sale. The competitive nature of these imports is strongly recognized by the trout farmers in central Canada and, in fact, volume purchasers would seem to prefer the consistent quality, dependability of delivery and lower wholesale price of the imported frozen product. Locally produced fresh trout, however, may have consumer preference on local markets (e.g. restaurants, cash and carry from trout farms, small retail outlets) if product quality is high.

Based on permits issued by local Fish Health Officers, interprovincial shipments consisted of only 0.01 million eggs and 0.13 million fingerlings into central Canada in 1981

TABLE 3. Imports of cultured trout, fresh or frozen, into Canada (essentially rainbow trout), 1965–81.[a]

Year	Quantity (tonnes)	Value ($000)	Price ($) per kg	Main supplier of trout	% into Ontario
1965	522	531	1.02	Denmark	
1966	339	375	1.11	Japan	
1967	455	549	1.21	Denmark	
1968	541	623	1.15	Denmark/Japan	
1969	420	577	1.37	Denmark/Japan	
1970	280	494	1.76	Japan/USA	
1971	680	1 014	1.49	Japan	
1972	750	1 003	1.34	Japan	12.5
1973	608	1 113	1.83	Japan	19.2
1974	862	1 815	2.11	Japan	24.8
1975	714	1 415	1.98		41.4
1976	701	1 782	2.54		37.5
1977	989	3 084	3.12		44.5
1978	1 076	3 630	3.37	USA/Japan	45.1
1979	1 065	3 829	3.60	USA	51.8
1980	1 121	4 237	3.78	USA	50.9
1981[b]	1 917	4 756	2.48	USA	30.2
Latest 5-year average	1 233.6	3 907	3.27	90% USA (Idaho)	44.5

[a] Sources: Canadian Fisheries Annual Statistical Review, Economic Policy Branch, DFO, Vol. 1–13; Blum (1982).

[b] Preliminary.

(Table 4). These transfers, principally rainbow trout, were largely to the prairie provinces from Ontario certified trout hatcheries. Interprovincial shipments following implementation of the Fish Health Regulations in 1977 have remained comparatively low (Table 5).

Ova and fingerling production by the private sector in Ontario would seem adequate to meet the local needs of the industry. Importation of stock to Ontario is under strict government surveillance and restrictions. However, trout farmers in the prairie provinces maintain a sustained dependence on eggs and fish brought into these provinces (Table 4). Of imports of foreign trout into Canada, some 55.0% of the eggs and 99.5% of the fingerling trout were purchased by the private sector in Alberta, Saskatchewan, and Manitoba. Imports to these provinces in 1981, from foreign and interprovincial sources (Table 6) totalled to over 5 million eggs (mostly from California) and 2 million rainbow fingerlings (mostly from South Dakota). The relative economic merits of importation versus local brood stock development in the prairie provinces is unclear. Undoubtedly there is a continual inflow of substantial quantities of ornamental fish into the central Canadian provinces, and possibly some bait fish, but without government scrutiny of quantity or quality. Likewise, no statistics on ornamental fish production or distribution in central Canada are available.

Imports of prepared fish foods into Canada are recorded by Statistics Canada (Preston, personal communication) as averaging 1.7 million kg annually over the past 5 years

TABLE 4. Canadian imports and interprovincial shipments of cultured salmonid eggs and fingerlings received by province/region, 1981.[a]

	International imports		Interprovincial shipments		Total	
Province/region	Eggs	Fingerlings	Eggs	Fingerlings	Eggs	Fingerlings
British Columbia	1.37 M	0.01 M	—	—	1.37 M	0.01 M
Alberta	3.01 M	0.93 M	—	0.12 M	3.01 M	1.05 M
Saskatchewan	0.17 M	0.57 M	—	—	0.17 M	0.57 M
Manitoba	2.15 M	0.50 M	0.01 M	—	2.16 M	0.50 M
Ontario	—	—[b]	—	0.01 M	—	0.01 M
Quebec	0.50 M	—	—	—	0.50 M	—
Maritimes	2.49 M	—	0.77 M	0.06 M	3.26 M	0.06 M
Newfoundland	—	—	—	0.02 M	—	0.02 M
Northwest Territories	—	—	—	0.01 M	—	0.01 M
Total	9.69 M	2.01 M	0.78 M	0.22 M	10.47 M	2.23 M
% into central region	55.0	99.5	1.3	59.1	51.0	95.5

[a] Source: Carey, personal communication.

[b] Negligible.

TABLE 5. Three-year comparison of Canadian imports and interprovincial shipments of cultured salmonid eggs and fingerlings.

	International imports		Interprovincial shipments		Total	
Year	Eggs	Fingerlings	Eggs	Fingerlings	Eggs	Fingerlings
1972[a]	8.96 M	4.08 M	5.88 M	0.72 M	14.84 M	4.80 M
1978[b]	7.19 M	1.74 M	0.47 M	0.05 M	7.66 M	1.79 M
1981[b]	9.69 M	2.01 M	0.78 M	0.22 M	10.47 M	2.23 M

[a] Source: MacCrimmon et al. (1974).

[b] Carey, personal communication.

TABLE 6. Canadian imports and incoming interprovincial shipments of cultured salmonid eggs and fingerlings by species, 1981.[a]

Species	International imports		Interprovincial shipments		Total	
	Eggs	Fingerlings	Eggs	Fingerlings	Eggs	Fingerlings
Rainbow trout	8.90 M	2.01 M	0.20 M	0.21 M	9.10 M	2.22 M
Brook trout	0.64 M	—	0.25 M	—	0.89 M	—
Lake trout	—	—	0.25 M	—	0.25 M	—
Cutthroat trout	0.10 M	—	—	—	0.10 M	—
Brown trout	0.05 M	—	—	—	0.05 M	—
Atlantic salmon	—	—	0.08 M	0.01 M	0.08 M	0.01 M
Total	9.69 M	2.01 M	0.78 M	0.22 M	10.47 M	2.23 M
% rainbow trout	91.8	100.0	25.4	96.4	86.9	99.6

[a] Source: Carey, personal communication.

TABLE 7. Imports of complete fish food into Canada by country of origin by quantity (Q:tonnes) and value (V:$,000), 1978–82).[a]

Year		Country						
		USA	Taiwan	W. Germany	Italy	Norway	Japan	C.I.T.C Total
1978	Q	1 114	37	—	—	—	—	1 313
	V	658	31	—	—	—	—	1 293
1979	Q	1 408	26	—	—	—	—	1 708
	V	942	39	—	—	—	—	1 893
1980	Q	1 818	54	79	1	11	19	1 988
	V	1 317	126	621	4	13	15	2 101
1981	Q	1 721	62	41	—	5	—	1 829
	V	1 421	102	564	—	7	—	2 093
1982	Q	—	—	—	—	—	—	1 680
	V	—	—	—	—	—	—	1 882
Average	Q	—	—	—	—	—	—	1 704
	V	—	—	—	—	—	—	1 852

[a] Source: Preston, personal communication.

(Table 7), with a value of some $1.85 million. This amount undoubtedly includes packaged feed for the lucrative tropical fish (ornamental) trade as well as formulated trout rations. Two fish feed manufacturers operate in Ontario and produce approximately 65% of the trout feed used in Canada. This approaches 90% of the market in Quebec and the prairie provinces (Byrne, personal communication).

LEGAL ASPECTS

Most, if not all, aquaculture activities are touched by various federal and provincial government regulations. These regulations relative to central Canada are concerned principally with the orderly development and administration of the aquaculture industry, protection of the health and welfare of indigenous fishes, and the protection of aquatic environments. The Canada Fisheries Act (Government of Canada 1932) and its Regulations assure a level of conformity in aquaculture policy among the four provinces of central Canada.

Despite differences in fisheries and environmental regulations among the four provinces of central Canada, actual policies concerning aquaculture principles and practice are remarkably similar. Most regulations are restrictive in nature but generally accepted by fish farmers as a safeguard to the future welfare of the industry. Specifics can be provided as Acts, Regulations, and guidelines by the appropriate Federal and Provincial Government agencies.

RESEARCH AND DEVELOPMENT

If aquaculture is defined in its broadest terms, much of the research in the aquatic sciences undertaken in government and university laboratories has potential bio-technological application in the controlled production of aquatic organisms for food and/or recreation. Much of the university research in this category is not identified as being aquaculture-related, nor is it funded as such. Research areas within this category include academic-type studies on fish ecology, behaviour, physiology, bio-energetics, limnology, hydrology, engineering, environmental quality, economics and marketing. These studies receive federal and provincial funding in the form of equipment and operating grants or contracts to faculty, and scholarships and bursaries to graduate students, to whom practical applications of their research findings to aquaculture may be an adjunctive consideration at best.

A second category of university research is recognized by governments as being specifically aquaculture-related, and is financed as such. These studies lie principally within the disciplines of fish nutrition, pathology and breeding. Major deficiencies are obvious in the bio-engineering and natural sciences, despite the urgency for inputs from these disciplines. Primary sources of funding for applied aquaculture research are the Science Subvention Program of the federal Department of Fisheries and Oceans; the Ontario Ministries of Natural Resources and Agriculture and Food; the Manitoba Department of Natural Resources; the Saskatchewan Research Council, Department of Tourism and Renewable Resources and Power Corporation; and the Alberta Department of Energy and Natural Resources. Total funding to university aquaculture researchers in central Canada from these sources is estimated at only $600,000, including allocations to the University of Manitoba from the Freshwater Institute (DFO) at Winnipeg. Aquaculture studies at universities also receive occasional support from other funding agencies such as present grants to the University of Guelph from the Canadian National Sportsmen's Fund (salmon genetics) and Wintario (aquaculture systems modelling).

Government research units in central Canada which can be identified specifically with aquaculture studies are the Maple Fisheries Laboratory of the Ontario Ministry of Natural Resources (fish genetics); the Fish Pathobiology and Aquaculture Sections of the Freshwater Institute at Winnipeg, including the Rockwood Experimental Fish Hatchery (Arctic charr and rainbow trout culture, hatchery biotechnology, diets, fish health, modelling); laboratories on the University of Saskatchewan campus of the Saskatchewan Research Council and the Department of Tourism and Natural Resources (trout farming technology); and scattered projects of the Alberta Department of Energy and Resources (trout and walleye culture). Funding of aquaculture-related studies is not easily identified from fiscal financial statements, but probably does not exceed the $650,000 budget (1981–82) of the federal Freshwater Institute for work in aquaculture and pathology.

Significant specific funding of aquaculture-related research to central Canadian universities, identified as such, is focused essentially at the University of Guelph (mainly nutrition, pathology, genetics, systems modelling), at the University of Manitoba (systems modelling, walleye culture, pothole trout farming, waste heat utilization), and at the University of Alberta (fish diseases, neurohormonal activation of spawning). Total specific annual government funding to these purposes is estimated at less than $750,000. Systems analysis, for example, undertaken at the University of Guelph, has produced two computer simulations. One model is concerned with the economics of trout farming, the other with the biological, environmental and managerial variables which affect trout growth and production (Joyner and Beamish 1983).

Government funding of university research and graduate student support in the natural, engineering and social sciences with potential application in the practice of aquaculture (for example, longtime studies on salmonid biology, ecology, and behaviour at the University of Guelph), but not necessarily identified as such by grantor or grantee, is substantial. The benefits of these expenditures to aquaculture are largely unexploited. Neither has the very considerable pool of academic expertise in both universities and government been adequately tapped to solve the many fundamental problems facing aquaculture development in central Canada.

The private sector (consultants and fish farmers) receives occasional funding from various government agencies, largely federal, for aquaculture-related and aquaculture projects. These include contractual agreements with the Department of Fisheries and Oceans (under $50,000 for central Canada since 1981), and unsolicited proposals (also administered by the Department of Supply and Services) made to the Program for Industry/Laboratory Projects (NRC), Industrial Research Assistance Program (NRC), Enterprise Development Program (Industry, Trade and Commerce), Industrial Energy Research and Development Program (Industry, Trade and Commerce), Industrial Energy Research and Development Program (Energy, Mines and Resources) and others (Pritchard 1980). Federal funds for private aquaculture projects in Canada have been directed principally to the east and west coasts rather than the central provinces. Because of the confidentiality (intellectual property) and shared-cost involvements, total payments to the private sector for aquaculture development cannot be readily calculated. Among earlier projects, modular aquaculture in Ontario supported by the federal government is noteworthy. A recently-concluded short-term study of the Ontario and Canadian aquaculture industry (stimulated by the Ontario Trout Farmers' Association) has been substantially supported through the Federal–Provincial Special Fisheries Employment Program. Recent funding of cage culture and multiple species projects by the Northern Ontario Rural Development Agreement (Federal/Provincial) is also worthy of note.

Direct benefits to government and private sector aquaculture resulting from past and present Canadian and provincial government investments in research and development are difficult to assess. This is especially so if improved cost benefit is the criterion. A prevalent concern in central Canada is an apparent tendency of government funding agencies to stress academic rather than more practical aspects of aquaculture-related research. It is argued that the direction of government and, especially, university research is unduly influenced by the personal initiatives of applicants for contractual or grant funding in which peer judgement (e.g. scientific papers) is a primary motivation. This may lead to the perpetuation and intensification of biological research not necessarily related to solving practical aquaculture problems, or to the development of aquaculture systems and technologies too costly for practical use by the private sector where profit is the goal. Funding agencies must, in the future, establish priorities and balances between academic research and practical aquaculture development.

The private sector has, on its own, made noteworthy progress in solving its own problems of production and cost efficiency. The most successful fish farming operations in central Canada are the result of individual commitment, ingenuity, and learned experience of the owner and/or manager. This ingenuity has included the application of biological and engineering principles to specific situations and requires individual and unique facility design and management strategies. From our survey, it is concluded that the private fish farmers (and government hatchery managers) in central Canada have not been given an adequate say in the formulation of aquaculture research policy, nor has their vast practical knowledge been used advantageously.

Support services to the aquacultural industry are a commitment of all provincial governments, and of the federal government especially in the prairie provinces. Principal activities include legislative controls, pathological and disease certification services, field extension services and aquaculture training programs. Diagnostic laboratory services are made available to trout farmers in all provinces, including stock certification as defined in the Fish Health Protection Regulations (Department of Fisheries and the Environment 1977). Also, improvements in fish diets and probably cost resulting from research in government and university laboratories are recognized by the industry as outstanding contributions to the development of an aquaculture industry in central Canada. Controls imposed by environmental agencies on the location and operation of aquacultural facilities in central Canada are generally acceptable to the industry, but governments are considered to have, perhaps, been too lenient. Only limited environmental research has been directed at either impacts of government and private fish hatcheries on ground, surface and receiving waters in central Canada, or potentials for waste nutrient utilization within existing or future aquacultural systems. Environmental agencies in all four provinces report that adequate general legislation for the preservation and protection of water resources are in place, but specific policies relative to existing and new government and private fish hatchery operations are obscure. Aesthetic issues, relative especially to potential cage culture in littoral waters of the Great Lakes and larger inland lakes of northern Ontario and the prairie provinces, have not been fully addressed, nor have past, present or future impacts of hatchery escapees on indigenous fish populations been adequately evaluated.

Incentives for the development of private sector aquaculture in central Canada, beyond the publication of research findings, occasional information bulletins and pamphlets and general guidelines on regulatory procedures, are limited essentially to occasional workshop and extensive courses on fish pond management and elementary trout culture, which, at least in Ontario, tend to be attended by hobbyists. Examples of such extension courses are those given by the University of Guelph and Ontario Ministry of Agriculture and Food, the Saskatchewan Research Council, and the Freshwater Institute. The intensive in-house training in fish culture provided by the Ontario Ministry of Natural Resources at the University of Guelph for government hatchery personnel is not yet offered to the private sector.

A token incentive has come also from a government broadening of the water resource base for aquaculture in the prairie provinces. In Manitoba, isolated water bodies located on crown lands are made available to trout farmers upon Department of Natural Resources approval and a nominal licence fee, while commercial trout farmers can apply for loans to purchase harvesting equipment from the Manitoba Agricultural Credit Corporation. In Saskatchewan, fish farming has recently been allowed in isolated northern lakes on provincial forests and is encouraged on Indian reserves. The economic potential of these opportunities is not specified.

Growing demands for increased public fishing opportunities, especially near centres of high human populations in all four provinces, are self-generating but stimulated by various government publications, for example, Farm Ponds in Ontario (Ayers et al. 1973). Such recreational angling, principally for trout, using dugout ponds, gravel pit excavations, impoundments and small lakes is provided by the government and private sector in each Province, and in Saskatchewan has been extended to include southern mine pit ponds and isolated forest-fringe lakes. As most of these are put–take fisheries dependent on plantings of hatchery-reared fish, incentives for the increased commercial production of trout for live sale of fingerling or catchable size now exist.

STATUS AND FUTURE OF AQUACULTURE

Ontario

Considerable surface and groundwater resources in Ontario are presently untapped by aquaculture, but it is unlikely that the use of these potential water sources for conventional types of fish farming particularly in southern Ontario, will be encouraged, or even permitted, by government because of environmental concerns. However, innovative approaches to aquaculture, especially trout farming, which conserve water and minimize impacts on river and lake ecosystems may be given more favourable consideration. These innovations cannot be technologically complex or costly if the product is to be marketed at a competitive price. While the extent of economic viability of individual fish farms is confidential, several family-operated businesses are known to yield very favourable profits over investment. These are not necessarily the larger operations. Existing trout farms are believed to be presently operating at about 60% of capacity.

Within the foreseeable future, the trout farming industry in Ontario will probably continue to produce localized low volume and high value products under less than ideal thermal regimes. If Ontario-produced trout are to be competitive with imported fish, principally from the United States, this objective requires more than improved biotechnology. It requires, also, enhanced attitudes towards marketing strategies including consistency of supply, product quality control and realistic stabilization of wholesale prices. With ever-increasing demands for public and private recreational fishing, especially near centres of population, increased sales of live fish to the private sector, and to government, look promising especially if quality fish (and government-certified) can be produced in quantity, and at a fair price. It is anticipated that the trout farmers may focus more strongly on the live sale component of the market in the future.

As long as the rainbow trout continues to be the 'sacred cow' of the fish farming industry in Ontario, aquaculture will continue to be stereotyped with the production of a species under climatic conditions less favourable than in many other regions of North America and the world. Except for the limited production of brook trout, and even less of blackbass, for live release, negligible attention has been given to either the production or the marketability of native or alien species for various purposes. It is expected that the future economic viability of the aquaculture industry in Ontario would be enhanced by a diversity of products serving a broader consumer base. Obviously, considerable research and market development would be required as new species and products become available for domestic sale.

The extent to which waste heat may be used to alleviate cold-water conditions in Ontario aquaculture is questionable. The concensus of opinion concerning proposals to utilize thermal effluents from power generating plants is that such operations would be too expensive and unreliable. Whether-or-not smaller sources of heated water from private industrial sources could be used for profitable aquaculture remains to be tested. Innovative use of solar energy, as presently used by several trout farmers to heat water for incubation and juvenile production, may not prove economically feasible even for small-scale production of larger fish. The principal criteria for waste heat utilization must be simplicity of operation, year-round dependability of both coldwater and warmwater sources, and profit justification. Two trout farmers are presently experimenting with seasonal cage culture in Great Lakes waters to take advantage of elevated summer water temperatures to rear marketable trout, while a third farmer pumps water of the most favourable available temperature on a year-round basis to a more-or-less conventional onshore facility.

While provincial policy on government aquaculture, including priorities for research and live release programs, is specified, that on private sector aquaculture is less clear beyond a commitment to provide assistance to fish farmers through extension, diagnostic, and research services provided by the Ontario Ministries of Natural Resources, and of Agriculture and Food. While the government would seem to favour the orderly growth of private sector aquaculture within the constraints imposed by the environment, its long-term potential in Ontario is unknown. Government involvements with private fish farming will probably remain a relatively small component of the overall provincial fisheries and agricultural program in the foreseeable future.

Manitoba

The key to successful extensive aquaculture in Manitoba is the presence of fishless yet productive lakes, especially those well-away from the major flyways of piscivorous birds. Trout farming is done principally in the pothole region in southwestern Manitoba where intensive research has been undertaken by the Freshwater Institute. Success has fallen short of original predictions for several reasons. The fish farmers are reported to be losing more fish to bird predation each year, and cormorant colonies are now present on many of the most productive and previously reliable lakes. Lakes in the interlake region of central Manitoba are quite shallow and problems occur, including low oxygen levels and nematode (*Contracaecum spiculigerus*) infestation, which cause mortalities or slow growth. Non-winterkill lakes in the north frequently produce large flavourful trout, but nutrient and climatic conditions at this latitude limit productivity and the economic viability of such operations.

Intensive aquaculture in Manitoba is limited because of cool ground water (av. 5°C). Growth rates in conventional hatchery and rearing facilities are generally too slow to produce a competitively priced trout in reasonable time. While the use of waste-heated water could be an answer, this source of energy from power generating stations is unreliable as existing thermal generating stations are operated as auxiliary stations to hydroelectric generation and come on line intermittently during peak demand periods. The Freshwater Institute has demonstrated the advantages of solar heating for increasing salmonid growth at the Rockwood Experimental Hatchery but, without government subsidization, it is unlikely that private operators can afford to invest in the equipment, or that costs could be recovered by unsubsidized fish production. With the present pattern of world oil prices, significant government support for research into alternate energy sources in the prairie provinces seems unlikely in the immediate future.

Relative to natural fisheries and other food production systems, aquaculture would seem not to have a high provincial government rating in Manitoba. Within the context of existing practices, the prevalent concept is that fish farming should not be encouraged beyond its present level. While low-scale aquaculture will no doubt persist as recreational or hobby ventures with modest economic benefits, the initial optimism that pothole trout farming in Manitoba would become a good business venture is not now evident. Innovative approaches to aquaculture, however, should not be discouraged.

Saskatchewan

In comparison to the other prairie provinces, the Government of Saskatchewan indicates a greater enthusiasm for the potentials of private sector aquaculture. It is anticipated that future developments will focus on extensive aquaculture utilizing the many untapped isolated small lakes, intensive cage culture, and the development of new hatchery facilities for the rearing of fingerling trout for live sale to fish farmers. A recent change in government policy which allows commercial fish farming in winterkill lakes of provincial forests is expected to result in moderate production increases. In view of the present extent of imports of eggs and especially fingerlings into the Province, a challenge faces the trout farming industry to provide seed stock (preferably certified) within the province, but cost benefits are not presently discernible.

Despite the continued enthusiasm of the provincial government, projections for the future see private sector trout farming remaining small-scale, with no major increase in private sector aquaculture beyond that servicing local markets. Problems which limit the present success and potentials of "pothole" aquaculture, i.e. summerkill, algae, predation by fish-eating birds and animals, diseases and muddy-flavour, simply will not go away. Cage culture of rainbow trout in lakes presents similar problems, with, for example, high mortality attributed to oxygen deficiencies and high summer epilimnetic water temperatures, disease, stunted fish growth and high operational costs. These factors would seem to significantly limit growth of the trout farming industry, and its future economic viability, unless innovative technologies can be developed, probably utilizing species other than (or in combination with) the rainbow trout.

Private sector aquaculture in Saskatchewan is a very minor producer of food in this strongly agricultural province. This imbalance is likely to continue indefinitely, but should not distract from a challenge to better utilize available water resources in Saskatchewan for commercial fish or invertebrate production.

Alberta

Within the province of Alberta, low priority is given to private sector aquaculture relative to other food production systems, including natural fisheries. More intensive management of natural fish populations, including traditional commercial species and rough fish species, coupled with the live release of salmonids from the sophisticated government hatchery at Calgary, is likely to be placed ahead of a major development of commercial aquaculture.

Both natural water supplies and climatic conditions are considered to present a serious constraint to the potential of fish farming in Alberta. Very limited suitable water sites in the province, combined with low winter and low groundwater temperatures, do not inspire optimism for substantially altered private sector aquaculture capabilities in the future. At present, the "pothole" trout farming industry relies on the importation of seed stock from the United States. This practice is likely to continue until such time as the trout farmers can compete favourably with the growth, quality and price of imported fish. While some experimental work is underway on the use of waste heat to elevate hatchery water temperatures, its economic feasibility in private sector aquaculture requires further study. As intensive cage culture has shown no real practical success, it is not recommended as a fish production system in Alberta lakes.

The most likely expansion of profitable private sector aquaculture would seem to lie in the production of salmonids, and perhaps other species, for live release into private and public recreational waters, especially near centres of population. The extent to which production of fish for live release may supplement or replace that of the Department of Energy and Natural Resources in the future is, at this time, conjectural.

GENERAL REMARKS

This paper provides an overview of the present status of aquaculture in the central Canadian provinces of Ontario, Manitoba, Saskatchewan, and Alberta. Each province has a unique set of biological, environmental, and economic conditions which affect the future of aquaculture development.

Culture and producton of preferred sport and food fishes for live release is a longtime commitment of all the provincial governments. This objective, in combination with habitat and user management, will continue to tax the financial and fish production capability of each province using existing and new hatchery facilities. With ever-increasing public demand for put–take angling, especially in streams, small lakes and man-made ponds near centres of population, there is evidence of a growing government need to place a greater reliance on private sector fish production for live release programs aimed at the improvement of public fishing opportunities. The future role which the private sector may play in bio-engineering, selective breeding, product development, and production of fish for this purpose would seem to be negotiable with government agencies.

Traditional concepts and practices continue to persist in both government and private sector aquaculture despite notable advances in facility design, a growing understanding of fish nutrition, pathology and genetics, and costly but limited experimentation with the use of solar energy, waste heat, water recirculation, pothole lakes and cage culture. While the economic feasibility of the more complex and costly neo-technologies in commercial fish farming is yet to be proven, several farmers in Ontario now use solar energy on a small scale to warm water for ova incubation and improving alevin growth. Waste nutrients from trout farm operations are, in some instances, being used to fertilize agricultural soils. Also, summer trout cage culture in warmed epilimnetic lake waters has resulted experimentally in a shortening of the time to domestic markets. However, advances in the efficient production of sport and food fishes by central Canadian aquaculture lag behind virtually all food-producing sectors within the agricultural industry in research and the application of scientific findings to protein production and marketing.

Substantial expansion of the present trout farming industry, using only conventional aquaculture practices, will be constrained by severe limitations in the availability of suitable surface and ground waters at accessible locations, and by necessary government policies relative to water withdrawal and wastewater discharge. Prairie pothole farming or the use of isolated northern lakes may be attractive from this standpoint, but other factors detract from the likely economic potentials of such operations on a large scale. Subject to major improvements in traditional hatchery practices, including the selection of species best suited to local environmental conditions, commercial aquaculture in central Canada would seem likely to remain a low volume industry producing a high value product.

In contrast to the rainbow trout which has been the principal focus of government-supported research, biotechnological capability for volume production of indigenous fish species of central Canada to advanced size for purposes of live release or food sale continues to be demonstrated only for the brook and lake trout, and more recently, the hybrid splake. Some success has been achieved with the experimental or low volume production of Arctic charr, maskinonge, and walleye to advanced size in government laboratories and hatcheries, but the extent of potential cost benefits to private sector aquaculture requires investigation. Present knowledge of the biology, ecology, and physiology of most indigenous fish is inadequate as a basis for predicting their potentials for profitable aquaculture in monoculture and polyculture systems. Research on likely native species, and the testing of prototype installations, are imperative should there be a sincere commitment to explore methods for the efficient culture of native bait, sport, and food fishes.

Possibilities for the commercial culture of exotic warmwater organisms (clams, snails, shrimps, catfish, carps, milkfish, tilapia, and others) using waste thermal energy have been casually proposed from time to time. Although the very limited Canadian research into the culture of warmwater exotic species has not yielded very promising results, potentials for the economically viable production of such organisms should not be ignored in the development of an aquaculture strategy for central Canada. Given the mandate, there is little doubt that Canadian biologists in government, universities and the private sector with *on-site experience* in subtropical and tropical aquaculture can provide biological assessment of a number of species, and develop appropriate pilot production facilities. Dependable sources of water and low cost thermal energy, plus adequate funding and freedom of action, would seem imperative, with a concensus that such projects would be better situated at private industial sites rather than at government-owned power plants. Introductions of alien species should, of course, proceed with caution and only under rigid government scrutiny.

Undoubtedly a variety of freshwater biological production systems for native and exotic plants, invertebrates, fish, and other animals can be developed by government and private sector specialists given appropriate time and funding. The extent, if any, to which the federal and provincial governments may wish to commit themselves to longterm subsidization of aquaculture through research, development and price support programs will be the major factor determining the rate of growth and direction of the aquacultural industry in central Canada. Whether-or-not the precedent of costly subsidization set for agriculture should be extended to aquaculture is a policy alternative which must be decided by government, especially in the absence of significant private sector speculative investment by major food industries or private investors.

At present, neither the long-term goals nor respective roles of government and private sectors relative to aquacul-

ture research and development in central Canada are clearly defined, although both anticipate an orderly growth and subsequent stabilization of the industry at an undefined level of production. While it is no doubt feasible to grow numerous freshwater aquacultural products at north temperate latitudes with the development of appropriate technologies, favourable markets and long-term cost benefits are less certain.

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DEVELOPMENT OF APPROPRIATE AQUACULTURE TECHNOLOGY

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ABSTRACT

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Aquaculture has received favourable international acclaim in recent years, being heralded as the solution to malnutrition in the developing world, as well as an innovative method of producing an increasing quantity of quality fish products in the advanced societies.

The extent of aquaculture development and successful commercial application in Canada is more perceived than real, and at the present time there are few tools or systems developed to satisfactorily determine the commercial and/or the technical performance of existing operations, let alone the potential for new opportunities. The unique and varied nature of the Canadian environment offers a challenge to our technical ingenuity, and while there are numerous constraints which might tend to inhibit development, there are some appropriate technologies, proven commercially viable in other countries, which deserve some research and application in Canada.

This paper identifies certain technologies which on *an integrated basis* may increase the commercial viability of existing and proposed new operations, and proposes an integrated strategy for their assessment and application.

INTRODUCTION

Visions of unlimited supplies of cold spring water or pristine streams, rivers, and oceans remain intact in the minds of the majority of Canada's population as well as overseas visitors. Such amenities alone, however, will not result in a vibrant aquaculture industry. It must be recognized that we have certain key disadvantages which, even at this stage of our aquaculture development, work against us.

From the freshwater aquaculture standpoint, we are subject to climatic conditions extending from temperate to severe, with wide swings of temperature making conventional culture systems commercially unstable. Although there are some exceptional locations offering high-quality water sources, these are usually remote from economic marketing channels. Those water supplies closer to markets are more often than not of dubious quality. In the case of the Ontario aquaculture activities (considered advanced in the Canadian context), which are generally left to the family unit, with only recent development of larger operations, the climatic conditions have a detrimental impact on production efficiency, and stability of supply. A professional market analysis of the Ontario trout industry carried out in late 1981, indicated an alarming negative attitude at the wholesale and retail level, the major suppliers and chains showing preference for imported Idaho products, because of stability of supply, price and quality.

In the face of unsympathetic environmental conditions, and external competition, the economic viability of many existing operations is questionable. The family units give the appearance of profitability because cost of land and facilities is usually omitted from the accounting system, together with the value of labour for the members of the family. Many operators find it necessary to diversify into equipment sales, "put and take" ponds, and public recreation facilities. In contrast, entrepreneurs wishing to enter into commercial aquaculture are, in many cases, astonished by the high capital cost of facilities in relation to the unexciting returns on their investment, a feeling shared by the banker. Figure 1, compares the profitability of a hypothetical existing facility operated as a family unit with that of a new facility operating on a fully commercial basis. It will be seen that the fixed costs of amortization and depreciation of the replicated facility seriously affect the viability of the enterprise.

There are technical and financial risks facing anyone operating, or proposing to develop, an aquaculture enterprise. Although comparison with the development of the Canadian poultry industry is no doubt overworked, it is relevant to draw certain comparisons. Present day Canadian aquaculture would appear to be equivalent to the poultry industry situation 30 years ago. It too had to develop the husbandry, nutritional, and technical standards appropriate to the Canadian environment. Canada is now a world leader in poultry production due to the concerted and cooperative efforts of specialists who wrestled with the imponderables of flock densities, temperature control, ammonia removal, and disease control. This industry has reached a stage of sophistication where the fourteen components of production costs can be monitored on a montly basis — all for a commodity wholesaling for $1.78/kg (81¢/lb). It may be argued that fish culture is much more complex than raising poultry, but perhaps there is something to learn from the comparison. While it is dangerous for an engineer or an economist to wander into the field of fish culture R & D, which is the biologist's domain, there would appear to be substantial, and growing, documentation indicating the optimum culture standards for various species, as well as a plethora of data on the advantages and pitfalls of water recycling systems, tankage design, impact of temperature control, fish densities, use of oxygen, potential of heated effluents, etc. While there are various examples of the adoption of such "innovations" elsewhere in the world, few are evident in Canada, even though the selective adoption of such techniques might be considered much more appropriate to Canada than anywhere else.

The present emphasis on the production of salmonid fish in Canadian commercial aquaculture, has, to some extent, restricted the range of potential applications for innovative techniques. The commercial culture of alternative

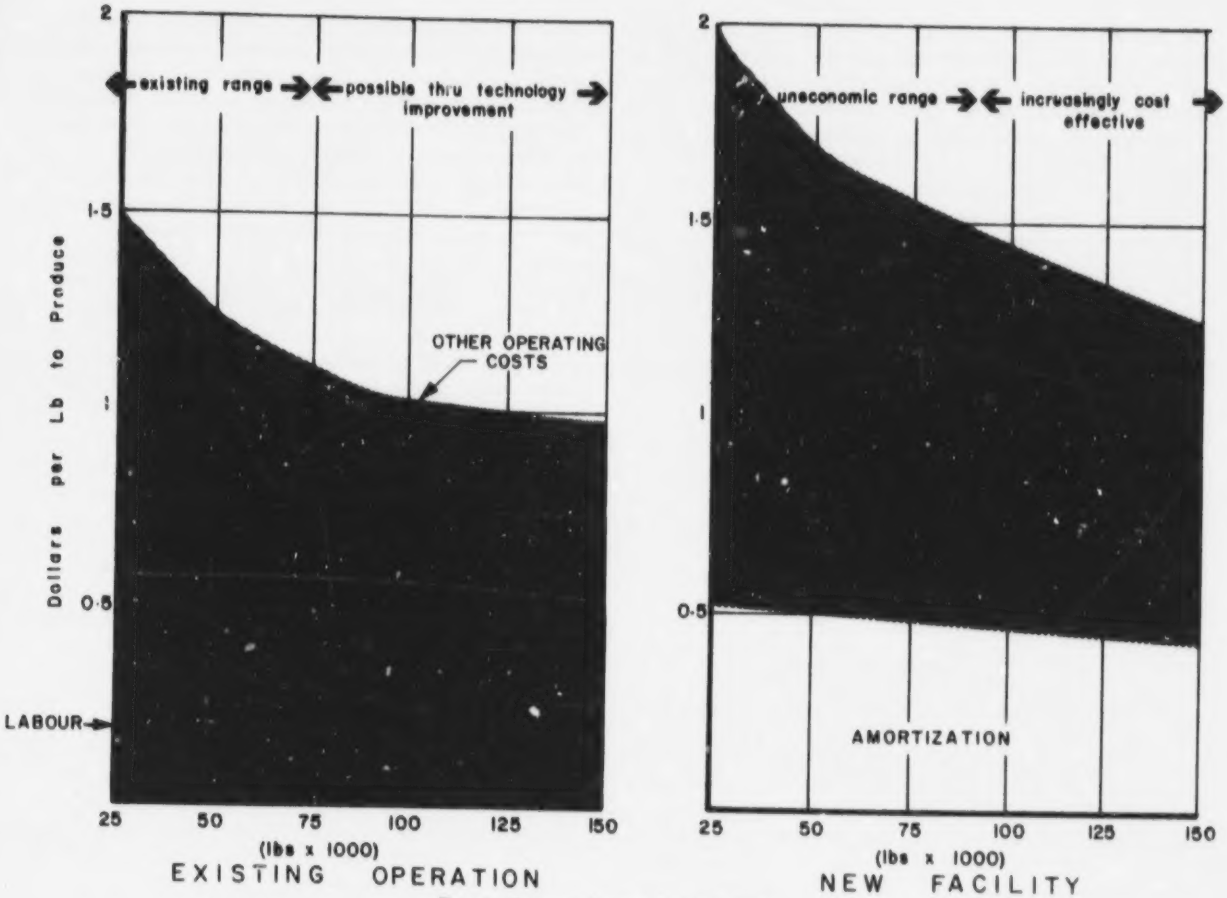


FIG. 1. Comparative production costs.

species will not be undertaken in Canada, even though the market opportunities and profitability appear to justify investment, until the technical and financial risks are understood.

In an attempt to justify the urgency for undertaking some coherent and integrated work on appropriate technology at both the pilot demonstration and commercial scales, it is pertinent to describe, in general terms, the beneficial impact of certain techniques, as perhaps retrofits to existing aquaculture facilities, as well as the basis of conceptual design of new facilities.

WATER CONDITIONING

The quality and quantity of water are always considered to be the critical determinants in developing a successful aquaculture operation. With few exceptions, fish culture facilities have initially been located and sized on the basis of an identified flowing spring, creek, or favourable groundwater well. While provincial governments usually prefer to seek out high-quality natural water supplies for rehabilitation and enhancement stocking needs, the commercial aquaculturalist must be cognizant of the trade-offs between facility location relative to markets, general operating costs, operations expansion/diversification, etc., when considering the water potential of his specific site. Potential sites are becoming harder to locate and certainly more remote, and provincial governments now use sophisticated air thermography techniques for the initial identification of new sites.

There are a variety of water reuse systems available to the commercial aquaculturalist, and most have the following advantages and drawbacks:

ADVANTAGES	DISADVANTAGES
Minimum make-up requirements.	Central systems complex and expensive.
Allows production expansion.	Increased energy consumption.
Allows economic use of heat for production acceleration.	Requires emergency power for fail-safe operation.
Facilities siting more flexible. More market oriented.	Smaller units dedicated to single fish culture tanks not yet proven in Canadian environment.

One specific biological filter which may have potential application in Canada is the Danish "bio-drum." In most existing situations, the production of small and medium scale fish farms is constrained by the finite limitations of the water supply. Usually facilities with expansion ambitions have had to resort to deep-well, groundwater supplies to supplement springs and/or artesian wells. The rising cost of energy for pumping is rapidly ruling out this solution as uneconomical.

Use of the "bio-drum", which is a simple, low energy consumer, designed on the basis of proven principles of biological filtration, could have the advantage of increasing a facilities' production by up to 8 times, operating on an available gravity flow. This, combined with savings, in deep-well pumping costs, and perhaps reduced mortalities due to better control of aquatic environment, in terms of aeration, economic temperature adjustment, etc., may make a marginal existing operation, or even a "hobby" type fish farm, much more efficient and commercially viable.

The concept of the bio-drum is based on trickling aeration and nitrification of ammonia utilizing thousands of small plastic balls which are contained in a rotating wire drum which can be partially submerged in a fish culture system. The unit floats in the water being treated because of the buoyancy of the balls and is slowly rotated by an electric motor. Microorganisms grown on the surface of the balls take up organic matter when submerged and alternating air contact supplies oxygen. A test installation is now being commissioned in eastern Ontario, as a retrofit to an existing fish farm, and even assuming very conservative increases in productivity, energy costs are indicated to reduce to less than 10% of existing bills while production increases by at least 65%.

FISH CONTAINMENT

Fish containment systems, be they pens, cages, earthen or lined ponds, concrete or fibreglass reinforced plastic (FRP) tanks, require special consideration in Canada. We have adopted many universally acceptable design configurations, but perhaps not spent enough effort on adaptation to our specific needs. Ph.D's have been awarded based on the relative merits of square circulating tanks versus circulars, all very necessary work, but in Canada we have additional considerations to assess and opportunities to take. Intensive culture in concrete tanks may be performing well in British Columbia, but in extreme winter temperatures in Northern Ontario, the freeze/thaw cycles play havoc with such construction materials. Use of conventional swimming depths prohibit economies in construction costs, as well as exposing large surface areas to severe climatic conditions, and taking up substantial areas of property.

Adoption of such techniques as the "bio-drum," previously discussed, would require the use of deeper culture tanks, and some economic form of shelter. Subject to thorough investigations of the problems to be encountered in the culture of various species in deep tanks, it is not difficult to demonstrate the construction advantages as well as the resultant added flexibility of introducing other techniques for greater production efficiency, (such as recycle systems, temperature control, use of oxygen, improved fish handling systems, and enclosures).

The following table gives some indication of benefits of deeper tanks, based only on the present range of containment costs at a rearing density of 32 kg/m^3:

Type of Containment	Cost Range for Conventional Depth	Cost Range for Twice Conventional Depth
Cages	C$1.00–2.00/kg	C$1.00–2.00/kg
Ponds	C$1.00–2.00/kg	C$0.60–1.20/kg
Concrete raceways	C$1.50–2.00/kg	C$1.00–1.40/kg
FRP circulating tanks	C$6.00–9.00/kg	C$4.00–6.50/kg
FRP raceways	C$4.00–9.00/kg	C$2.75–6.20/kg

If rearing density could be retained when operating at twice the conventional depth, the resultant saving in the cost of fish production would range from approximately 2¢ to 20¢/kg, based on the amortization period of 15 years for installed tankage. In addition to the apparent cost savings for the containment units, for a given production level, deeper tankage would produce a more compact layout, and economies in piping and fittings, as well as providing the foundation for other production improvement techniques.

THERMAL AQUACULTURE

Canada is considerably behind Europe, Japan, and the United States in the introduction of thermal aquaculture. While numerous feasibility and pre-investment studies have been carried out, few have reached the operational stage. The energy options available for thermal aquaculture include:

1) Solar — collectors and ponds.
2) Conventional heating systems.
3) Heat pumps.
4) Thermal effluent from power stations.
5) Industrial process waste heat.

The application, and relative merits of these thermal options, in the Canadian context, may be summarized as follows:

Solar Collectors — The Department of Fisheries and Oceans experimental fish culture station in Manitoba is one of the few solar projects of consequence. The initial system, installed in 1978, operates on propylene glycol and water to provide 70% of the annual heating requirements of a small building housing 12 fish tanks circulating through biological filters with 10% make-up supply. The system proved successful, and the second phase, designed to satisfy 100% of the hatchery's water heating needs has been implemented. The new collectors contain freon gas which transports the sun's heat into the glycol loop. Over 900 m^2 of panels are installed, water being heated from 6 to 12°C. The Biological Station in St. Andrews is also equipped with a solar heat collector system for the in-house fish and shellfish rearing programs.

The Ontario Ministry of Energy, with the cooperation of the provincial Ministry of Natural Resources, has recently initiated a feasibility study to determine the potential for solar heat at a major fish culture facility in Northern Ontario.

A few commercial fish farmers have installed modest solar systems, principally on incubation and early rearing, however no major commercial projects are in evidence.

Government funding assistance encourages further installations, this is essential, as systems have high capital investment characteristics, and the cost effectiveness is questionable over the normally acceptable commercial pay-back criteria. Integrated with small scale recycle systems there may be some economic advantage in low make-up water volume systems.

Solar Ponds — The use of large plastic bags, resting on insulation and covered with greenhouse glazing, for water heating has been tested in the U.S. Southwest, and also tried at the Wolf Lake Fish Hatchery in Michigan. There would appear to be little chance of effective operation in cold climates, as the bags cannot be used after ice formation, and in the case of direct-from-the-bag-water-use, Michigan discovered that certain elements in the plastic had an adverse effect on fish.

Conventional Heating Systems — The rising cost of fossil fuels prohibits consideration of conventional fuel heating systems except for low make-up recycle aquaculture operations. Some studies have been carried out on the use of wood residues and other biomass alternative resources which may prove economically viable if fish culture facilities are in proximity to cheap energy sources. Government funding has been used to implement some demonstration projects, principally agricultural, utilizing biomass fuels. Cost effectiveness has been demonstrated in comparison with fossil fuels, however the high capital cost of the necessary combustion equipment would suggest that such applications may be marginal in commercial aquaculture unless government support was forthcoming.

Heat Pumps — With the exception of aquaculture projects associated with economically available waste energy, the use of heat pumps offers the best potential for temperature control in fish culture processes. There are an increasing number of suppliers of such equipment in Europe and the United States, in size ranges up to 1 000 L/min at temperature differentials of 2–5°C. Operating costs are less than one-quarter of the equivalent coventional heating system output. Heat pump application is only logical when integrated with recycle operations, thereby optimizing energy consumption and scaling down the heat pump size. It is evident that high-capacity heat pumps requiring custom design are expensive to produce, and could not, at the present time, result in commercially viable aquaculture applications.

Power Station Thermal Effluent — Thermal effluent aquaculture has been the preoccupation of biologists, scientists and engineers for a number of years. In the case of Canada, investigations commenced in the 1960s, and apart from the production of numerous feasibility studies, and the occasional demonstration project we are not much further ahead in developing economically viable aquaculture systems utilizing this technique. Europe, Japan, and the United States have already gone past the introductory stage of development and the limitations and pitfalls have been identified. Canada could be the beneficiary, but there appears to be an intangible inertia preventing progress. There are several reasons for this apparent reluctance, namely:

1) The capital cost of commercial scale facilities are substantial, and the majority of feasibility studies have indicated no exceptionally good returns on investment for the perceived risks involved.
2) Only one concerted effort has been made to establish pilot-scale operations in Canada, and it is understood that this project, in New Brunswick, has now reached commercial production levels. However, there are no coordinated investigations underway to quantify the risks of intensive and semi-intensive culture in the Canadian context.
3) Preoccupation with salmonid aquaculture has tended to place emphasis on the inability of the power station to provide the optimum environment for salmonids. We must be perceptive enough to consider alternative species, and diseasonal methods of culture to optimize the use of the heated effluent and the culture facilities.
4) Power generation in Canada is owned and operated by government agencies, and the investigation of the technical and economic opportunities of utilizing heated effluent has been sponsored, principally, by government bodies with little input from private enterprise, which usually has a clearer understanding of what constitutes economic viability and how to interpret financial risk.
5) Power authorities have the responsibility to produce energy for the consumer, and few provinces pursue the wider mandate of promoting the utilization of by-product energies.
6) By definition, thermal effluent is low grade heat. Such heat has advantages for direct use in aquaculture systems, provided any water quality variables are controllable within culture limits.

Clearly, power station thermal effluent could be one of the major opportunities for Canadian commercial aquaculture, and we should be amongst the world leaders in this technology. The majority of power stations are sited on lakes, rivers, and oceans, using both fresh and salt water for condensor cooling, and most are in climatic locations with fluctuating summer/winter temperatures which can be used to advantage. Canadian fossil fuel and nuclear stations are, in general, on year-round operation, and the instability of shutdown would be an uncommon occurrence. There are, of course, a number of water quality concerns to be addressed, including biofouling control, trace contaminants, and radionuclides, however, in the recent assessment of an Ontario nuclear power station, the water quality proved to be satisfactory and stable for the requisite aquatic environment, but the real difficulty cited was the negative attitude of the public to nuclear power in general and to the perception of dangers in associated fish culture in particular.

Numerous analyses have indicated that the culture of salmonids alone would be an uneconomic strategy, when capital costs of facilities and heated effluent pipelines were considered. The alternating production of warm and cold water species is one solution which would spread the annual operating and amortization costs over stable year-round commercial sales. Such diseasonal aquaculture has been attempted elsewhere, and proven to be economically viable with fast growing species, adapted to high density culture. One marketable species which would have some promise in Canadian commercial aquaculture is the eel, and there are numerous other warm and cold water species of potential, however, provincial governments must agree to sanction and culture of such species prior to commercial culture becoming a reality.

Canadian aquaculture could benefit from the development of power plant thermal effluent opportunities, and pilot-scale projects should be given some encouragement now to prove out technical and economic viability.

Industrial Process Waste Heat — The high profile of power station thermal effluent research and demonstration has overshadowed the potential of utilizing industrial process heat surpluses. Sporadic investigations have been carried out at natural gas compressor stations, wood industries by-product energy producing systems, etc., with a lack of success. Unfortunately, the identification of industrial waste heat opportunities is a much more difficult task than locating power stations, also the encouragement of energy conservation measures may be assumed to have reduced the chance of identifying appropriate aquaculture sites. But it would be a mistake to consider such waste energy sources as insignificant, and we should be making a determined effort to identify potential industries which could provide commercial aquaculture support. The largest energy users in Canada are:

1) Industrial chemicals
2) Iron and steel mills
3) Pulp and paper mills
4) Smelting and refining

Naturally the largest users are not necessarily the producers of equivalently large quantities of waste heat, but these industries do have some characteristics important to aquaculture, namely:

1) Such industries are widely spread throughout the country, and if technically appropriate, could result in the widening of commercial aquaculture activities across the country.
2) Although industries normally operate on closed loop energy processes, cooling by condensors or air towers is commonplace, and waste process heat is usually of higher grade than available at power stations. Such higher grade heat may result in the economical use of heat exchangers to raise the temperature of any available and acceptable natural water supplies.
3) Selected industries may consider commercial or demonstration aquaculture an attractive diversification to invest in, not only as a profitable venture, but also because of the beneficial public relations merit such activities would attract.

Industrial process waste energy has, at least, equivalent potential for thermal aquaculture as power station heated effluent, with some marked advantages. In other countries, industry has taken the initiative in diversifying into commercial aquaculture, once pilot projects have established the extent of risks involved. Unlike power station heated effluents, stable temperature regimes might be possible on a year-round basis, allowing the production of higher quality products to regular market outlets, thus challenging a number of imported products.

OXYGEN ENRICHMENT

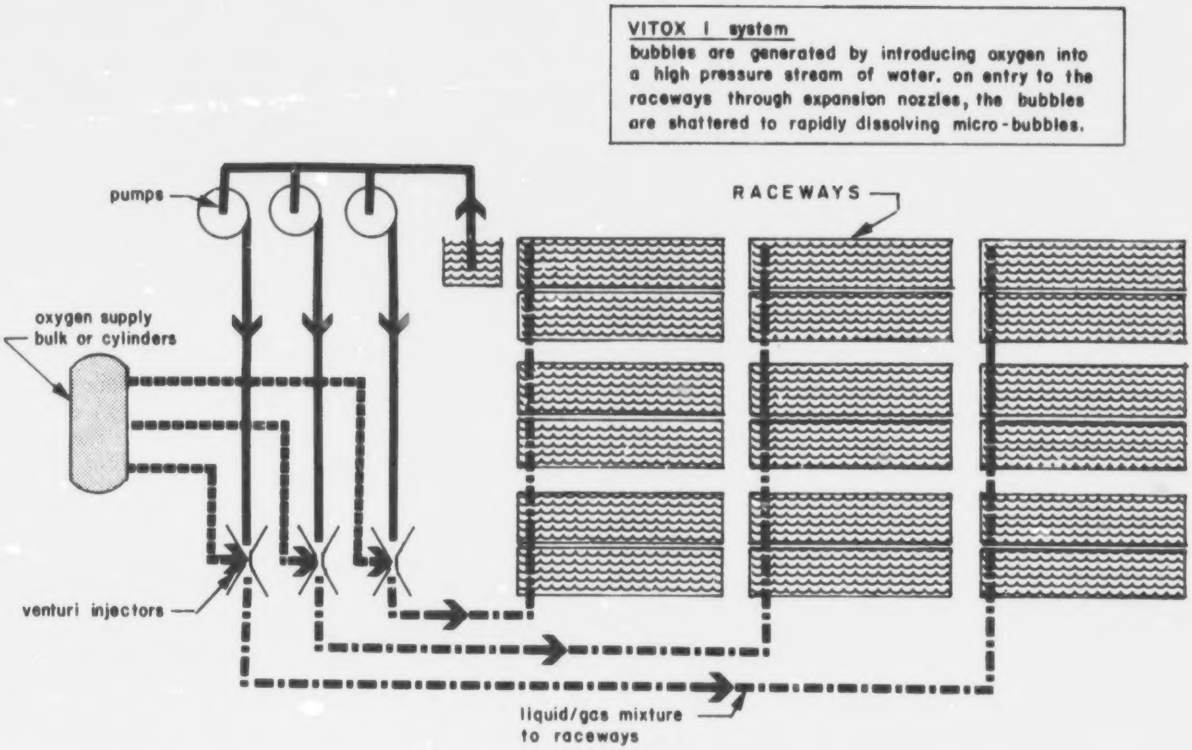
In the 1970s, in Great Britain, commercial fish culture operations took an important step by introducing oxygen as a technique to optimize the production of marketable size fish. Oxygen was injected to allow increased density culture, and equally important, to reduce water flows through the use of re-circulation systems. Installed systems have proven to be technically and economically viable. Several commercial aquaculture operations were established in the U.K. by a subsidiary of the BOC Group, successfully culturing fresh and salt water fish, and attaining the requisite quality and stability of supply to satisfy such customers as Marks and Spencer, the major British chain store group. This operation is now in the hands of Kraft
International Aquaculture, and continuing its expansion of commercial operations into various locations in Europe and, it is understood, the United States.

Only one major commercial scale oxygen enrichment facility is in operation in Canada, located in Ontario. This modern, high production, commercial trout farm has operated for more than two years with oxygen injection, utilizing the CANOX Vitox 1 venturi system (see Fig. 2) which supplies a liquid/gas mixture to concrete raceways, of conventional depth, operating on a three-pass system. The liquid/gas mixture is injected at the inlet end of each pass. The rearing density is said to have exceeded 75 kg/m^3 with rainbow trout. This density is somewhat less than that attained with oxygen at the Limestone Springs facility in Pennsylvania, where the rearing density exceeded 100 kg/m^3.

Records of the oxygen supply and facility charge costs indicate that the additional cost of fish production amounts to less than 10¢/kg, and in fact this may be a conservative figure. It must be cautioned, however, that the oxygen supply cost increases substantially as delivered quantities reduce. Nevertheless, in aquaculture operations exceeding 75 t production annually, the use of oxygen has some potential, namely:

1) The production capacity of an existing operation could be more than doubled without increasing rearing space or imposing additions to the facility amortization payments. Naturally certain operating costs will increase relative to the capacity expansion, however, the overall cost per kilogram of fish produced will reduce. The beneficial impact of oxygen usage may be less apparent to the small, family unit operations where the costs of property and facilities may not be assessed as components of operating costs.
2) New facilities could be designed on compact layouts, integrating other techniques, including deep tank design, temperature control, and re-circulation. Economies of scale could be achieved, and capital costs for facilities development reduced.

At the present time there are few aquaculture operations utilizing oxygen enrichment in North America, and no pilot projects located in Canada. The single Canadian commercial facility using oxygen demonstrated remarkable confidence in experimental and production investigations carried out elsewhere when deciding to install the requisite equipment. Many other fish farmers could improve on production through this technique, but data on the technical and cost implications are sparse, and not always relevant to the range and characteristics of existing and proposed fish culture operations in this country.



VITOX I system
bubbles are generated by introducing oxygen into a high pressure stream of water. on entry to the raceways through expansion nozzles, the bubbles are shattered to rapidly dissolving micro-bubbles.

FIG. 2. Oxygen application in aquaculture.

PILOT PLANT PROGRAMMES

The previous sections of this paper have identified a number of facilities and production improvement techniques which may have specific benefits to Canadian commercial aquaculture. In most cases, the techniques have been well-documented through research undertaken in Canada and elsewhere, but we lack an intermediate step in attempting to transfer such techniques into viable production operations. To attract existing aquaculturists or potential investors we must implement the necessary pilot plant programmes to demonstrate viability.

But how can such pilot projects be implemented? Although the establishment of some national aquaculture centre would be an ideal solution, such a development may take a considerable time to materialize — but the opportunities need to be assessed now. The justification for pilot plant programmes was succinctly expressed in the United States, over 10 years ago, by the regional Aquaculture Workshops sponsored by the National Oceanic and Atmospheric Administration. Their remarks concluded:

> "As a prerequisite to commercial operations the workshops recommended the establishment of pilot-farms to translate laboratory technology into operational techniques. Until such farms are established, extrapolation of economically viable operations from laboratory results is largely speculative."

> "A primary objective of full-scale pilot farms would be the development of required engineering skills. Scientists themselves stated that they have meagre information on what equipment is needed for pumping, feed distribution and pollution control. Nor did they know precisely what it will cost, nor what is required to make it function as an integrated system. The field of aquaculture was felt to be overdue for systems and production engineers who possess a thorough understanding of the relevant biological constraints."

If it is agreed that Canadian aquaculture could benefit from the application of innovative technologies appropriate to our specific environment, an integrated pilot programme is required. It may be argued that current projects such as pen and cage culture trials in B.C. or the Maritimes, the rearing of salmon smolts and trout in heated effluent in New Brunswick, the prospect of trout culture utilizing the energy surpluses of a natural gas compressor station in Northern Ontario, or cage culture in Georgian Bay constitutes some kind of a development programme. It is true that federal and provincial agencies encourage and assist in technology demonstration, but the emphasis appears less than that traditionally placed on R&D through universities or the government agencies' science oriented groups.

The intricacies of organizing technical directorates are outside the capabilities of the writer, but if commercial aquaculture was a mature industry in Canada, comparable to the forestry or certain agricultural operations for example, we would see the emergence of an industry development group consisting not only of government and academic members, but including representatives from the commercial operators, equipment producers, and consultants in facilities design, operation, business management and marketing. Such a group of specialists could, perhaps, develop some long-term strategies and priorities, as well as provide guidance to existing or aspiring aquaculturalists with innovative technical and/or commercial ideas. But the formation of such a group of specialists does not necessarily imply that an integrated technology development programme will be funded by government, private enterprise or a combination of both. It is unlikely that aquaculture could qualify for the equivalent of the multi-million dollar facility dedicated to ocean fisheries development, particularly in recessional times. Therefore, if any immediate action in technology application is to take place we must show some ingenuity by developing pilot projects around appropriate existing commercial operations or any other available facilities having the necessary infrastructure which would meet the requirements of integrated pilot programmes.

FACILITIES FOR TECHNOLOGY DEVELOPMENT

There are probably a number of industrial or government facilities throughout Canada that may have potential for adaptation to pilot scale aquaculture, at both fresh and saltwater locations. With some innovative retrofit design considerations it may be possible to develop pilot programmes at modest cost. One such example in Ontario, which is worthy of description, is a redundant water pollution control plant located only 1 200 m from the Pickering nuclear generating station operated by Ontario Hydro. Figure 3 indicates the general location of the W.P.C.P. relative to the power station heated effluent channel, and the basic components within the plant.

As will be seen, a number of large volume concrete tanks exist. These tanks were used for primary and final clarification, and activated sludge aeration. The service building housed mechanical/electrical equipment, chlorine system, laboratory, and office areas.

In terms of conventional aquaculture systems, the Pickering facility offers no attraction, however the facility would provide an economical proving-ground for some sys-

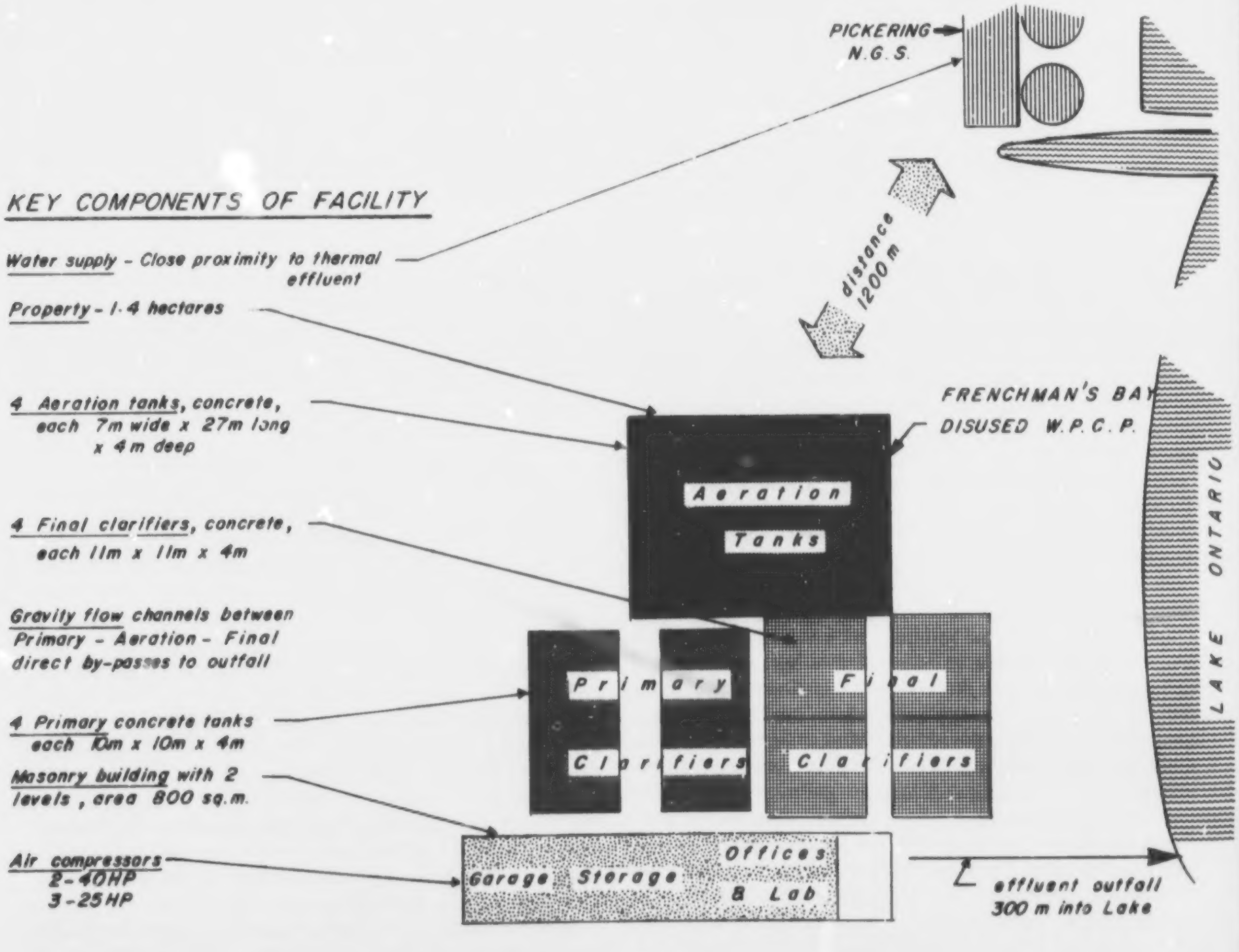

PICKERING N.G.S.
KEY COMPONENTS OF FACILITY
Water supply - Close proximity to thermal effluent
distance 1200 m
Property - 1.4 hectares
4 Aeration tanks, concrete, each 7m wide x 27m long x 4m deep
FRENCHMAN'S BAY
DISUSED W.P.C.P.
Aeration Tanks
4 Final clarifiers, concrete, each 11m x 11m x 4m
LAKE ONTARIO
Gravity flow channels between Primary - Aeration - Final direct by-passes to outfall
Primary Clarifiers
Final Clarifiers
4 Primary concrete tanks each 10m x 10m x 4m
Masonry building with 2 levels, area 800 sq.m.
Air compressors 2-40HP 3-25HP
Garage
Storage
Offices & Lab
effluent outfall 300 m into Lake

FIG. 3. Example of aquaculture retrofit potential.

tems which, if successful could lead to commercial viability. The key advantages of this site are:

1) Close proximity of stable supply of nonchlorinated heated effluent.
2) Minimal water supply and retrofit costs.
3) Opportunity to undertake both conventional and deep tank culture of various species, on a year-round or diseasonal basis. In addition to salmonids, the opportunities for culture of eels, perch, walleye, and sturgeon could be evaluated together with other high value species.
4) The use of pure oxygen could be evaluated for various species cultures.
5) Culture temperatures could be adjusted through the use of heat pumps.
6) Recycle systems integrated with the use of heated effluent, deep tanks and/or oxygen could be evaluated.

Projects such as that described, which require only modest funding for the development of pilot-scale operations, probably exist in all provinces. Those dedicated to the successful development of commercial aquaculture in Canada should take the initiative to ensure that facilities for testing out appropriate technologies are funded, so that existing aquaculturalists and potential investors are equipped with reliable data upon which they can judge the technical and economic viability of their options.

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RISK IN CANADIAN AQUACULTURE VENTURES

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ABSTRACT

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Failure rates of intensified commercial aquaculture at the international level are inordinately high. If aquaculture in Canada is to attract the sophisticated investor, to develop and to survive, then attention must be focused on reducing the high risk nature of the industry. In part, this can be accomplished by directing government support: to accord aquaculture national status; to introduce long-term tax incentives; to remove unequal treatment between terrestial and aquatic farming; to simplify permit procedures; and, in cooperation with industry and universities, to improve systems design; to improve and cost-reduce feed; to improve quality and develop high quality standards; to popularize preventive medicine; and to develop better and more environmentally acceptable disease control agents. For industry's part, aquaculture must be treated as a business, and attention must be directed with equal intensity to management and sales as previous attention has been directed to production. Training and educational institutions will be required to provide appropriate continuing education or extension courses in management and technology.

INTRODUCTION

With the growing recognition in North America of aquaculture as a protein source, it becomes clear that the present risks associated with the industry must be substantially reduced if a viable industry is to develop and flourish.

To examine risk reduction in Canadian aquaculture some assumptions will be stated, followed by a brief explanation of terms. Risks will be arbitrarily classified, then examined relative to enterprise planning in: production, sales, technology, education, and finance. Both existing and required infrastructural support will be identified as a prerequisite for sound business planning. The assessment will focus on the highly subjective state of risk in the aquaculture industry and conclude with a discussion and a brief summary.

RISK AND INFRASTRUCTURE

The examination of support systems to reduce risk in Canadian aquaculture is based on the following assumptions:

1) Cold and temperate water aquaculture is a high risk industry.
2) The aquaculturist is familiar with the demographic data available, and is at least intuitively aware of the market and technology.

and the condition that:

3) The assessment occurs at the pre-investment stage.

Further, it is necessary to define risk and identify the broad areas in which infrastructural support is available.

The term "fish" will be used throughout this paper to mean all aquatic animals, and will include molluscs and crustaceans as well as fin fish.

Risk

There are many ways of viewing risk. For instance, risk to a scientist raises such concerns as, what happens:

1) if a salmon population is neutered and released, will it remain close to the terminal fishery and consume all subsequent smolts? or,
2) if chum eggs are imported from Japan, what new disease might be introduced? or,
3) if grass carp are introduced to control noxious weed growth, will their presence eventually wipe out other indigenous species?

Since the technological risks are based on insufficient scientific information, the biologist will either experiment until the outcome is predictable and reproducible, or conclude that the risks are too high and do nothing. Personal liability is not a consideration.

To the entrepreneur, risk raises such questions as:

1) what is the probability of losing all capital assets? or,
2) how long will it be before the enterprise is in a financially responsible position? or,
3) how much personal security must be advanced in order to raise the remaining funds for project commencement?

Personal liability is now involved.

Webster defines risk as the "possibility of loss or injury; a dangerous element or factor; the chance of loss." Although the realities are evident in such a definition, it serves little purpose to discuss reducing risk under those conditions when the prescription clearly is to avoid involvement altogether. Therefore it becomes imperative that a working definition of risk be established.

Bannister and Bawcutt (1981) suggest that risk is the "potential variability in the future outcome (of a stated situation) due to uncertainty." Whereas Kobrin (1981) maintains that semantic confusion can be avoided if risk is considered to exist in the three states: certainty, objective uncertainty, and subjective uncertainty.

For the purpose of this paper, risk will be considered as a state of uncertainty wherein the opinions of the probability of events occurring are based upon perceptions that are functions of available information and previous experience. Kobrin calls this subjective uncertainty, and clearly this is the state of risk that prevails in the Canadian aquaculture industry today.

Table 1 provides an arbitrary list of risks and the levels of control the aquaculturist has over them.

TABLE 1. A classification of risks, modified slightly from Bannister and Bawcutt (1981).

PHYSICAL LOSS/PROPERTY DAMAGE LIABILITY BUSINESS INTERRUPTION	Potentially manageable (and insurable)
MANAGEMENT PERSONNEL WASTAGE	Directly controllable by management
TECHNOLOGY POLITICS SOCIETY ENVIRONMENT	Not directly controllable by management May have positive or negative effect Manageable to greater or lesser extent

Within the above types of risks, the first three, Physical Loss/Property Damage, Liability, and Business Interruption are at least partially manageable and insurable. The levels of risk have been largely determined and are reflected in the premiums should the option to insure be exercised.

Management, Personnel, and Wastage are internal risks that can be controlled directly by the company. These three areas give rise to the subjective uncertainty so often found in most private businesses, and to even a greater degree in an aquaculture venture.

The remaining four risks, Technology, Politics, Society, and Environment are external to the organization and cannot be controlled by the company, although they are manageable to a greater or lesser extent.

Infrastructure

The infrastructural support available to assist and maintain a viable aquaculture industry is broadly depicted in Table 2. Some of the support is weak, some, frustrating, but in most cases it is capable of providing the necessary assistance.

TABLE 2. The infrastructural support available in Canada to assist and maintain a viable aquaculture industry.

GOVERNMENTAL:	including roads, specifications, legalities, leases, policing, research back-up, etc.
INDUSTRIAL:	including supplies, transportation, marketing, purchasing, work force, etc.
INSTITUTIONAL:	including education, finance and insurance
COMMUNICATION:	including scientific literature, conferences, popular media, telephone, etc.
SOCIAL:	including values, behaviour, beliefs, community organization, etc.

Although the risks have been classified, it will be more useful if the discussion that follows is typical of the approach an entrepreneur would make when planning an aquaculture venture. That approach would consider the business aspects of production, sales, technology, education, and finance. While technology is classified as a risk, it is also a critical planning aspect in cold and temperate water aquaculture because technological sophistication is required for the heavily capitalized intensified systems.

BUSINESS PLANNING

Business planning in aquaculture requires thoroughly investigating at least five major aspects. These are production, sales, technology, education, and finance.

However, one cannot discuss business planning without first commenting on the legal constraints and the plethora of permits and regulations created by all three levels of government. An excellent review of the present Canadian permit scenario is found in B. H. Wildsmith's *Aquaculture: The Legal Framework*, (1982).

This proliferation of permits is not unique to Canada. The State of Hawaii, for instance, recognized this problem when it promulgated its Aquaculture Plan in 1978, wherein it recommended, among many things, that a single master permit application form be instituted. Despite this excellent intention, the single permit approach has not been successful. Indeed, the situation surrounding each application has been made so complex that no single permit-granting body has the expertise to evaluate and approve. If the experience in Hawaii is indicative, and indeed Hawaii is one of the leading states for aquaculture development in the United States, then Canadian efforts to simplify regulations will be a long and arduous task. The task, nonetheless, must be undertaken.

The conduct of some government agencies towards aquaculture is uncoordinated and sometimes internally contradictory, which is a severe impediment to investment. In fact, many potential entrepreneurs indicate that the confusion, time demands, and general uncertainty involved in obtaining licenses and approvals to operate have contributed to the largest single risk threshold that they must overcome.

It has also been suggested that aquaculture is a threat to the more traditional forms of fishing. The result has been to downgrade aquaculture and assign it low priority.

Production

Production planning includes such elements as operating costs in feed, labour, mortalities, sales, administration, energy, maintenance, and transportation; and systems engineering and design in equipment, technology, quality control, innovation, security, and yield.

Much of the available data for operating costs will be site specific, and therefore difficult to quantify for forecasting. Feed, labour, and mortalities, however, comprise the major costs.

Feed and labour costs are predictable, but mortalities are not. This represents a significant risk to the aquaculturist. Considered a risk in Wastage, mortalities most frequently result from disease. A significant disease problem could very well wipe out an operation. Although business interruption insurance is available, the costs are high and the option to assume full risk by self-insuring may be preferred.

Farm yield unquestionably determines the financial viability of the firm. Both active and passive investors are vitally concerned with the output. Yet, as with terrestrial farming, there is no guarantee that a product will be available for marketing. Therefore, careful consideration must be given by the aquaculturist to forecasting farm output.

Best and worst forecasts are mandatory, wherein all possible parameters that will affect the operation of the business are identified. It is necessary to document these variables, and offer alternative approaches to controlling them. The new venture is then designed in a manner that will minimize the risk of failure — an obvious understatement, but seldom remembered. Aquaculture attracts the outdoors person. The tremendous appeal to be on or near the water often clouds rational business thinking. Since the life-style can be attractive, a hobby farm can materialize with no real thought to being a business.

As previously mentioned, cold and temperate water aquaculture requires intensification, which immediately introduces such potentially stress-inducing conditions as overcrowding, low oxygen and high ammonia conditions. Although government support is available to identify diseases and offer prescriptions for control, it is inadequate in disseminating methods for preventive medicine and system designs for stress reduction.

Feed costs can represent over 50% of the total operating expenses. This situation will cause any potential investor to thoroughly examine cost reduction or diet improvement plans considered by feed producers. Supportive infrastructure should be directed towards improving this costly item.

Other costs that are often underestimated include transportation and maintenance: transportation because of unforeseen emergencies, and maintenance because of possible remoteness of site.

Quality of the end product is frequently ignored in the early stages of planning. In fact, product quality receives so little attention from many North American retailers that the aquaculturist has few standards to guide him. Minimal infrastructural support exists to provide quality criteria or quality improvement methods. Yet, this is an area which is always given primary consideration by Japanese aquaculturists, probably the most experienced entrepreneurs in the field and certainly successful in servicing their own most particular and quality conscious seafood market.

Sales

Sales planning first requires an examination of market demand, its seasonality and stability; prices, their seasonality and stability; and competition. A plan will be designed to consider such elements as target market and location, condition of product (fresh, frozen, or canned), distribution, promotion, and advertising.

However, insufficient effort is made within the industry to sell. This opinion exists at least in North America and Europe, and only just now is being voiced with audible volume.

Emphasis in Canada has been completely centred on production, resulting in products of varying quality, often too highly priced and competing with other existing, more readily available, protein sources. Furthermore, Canadians are not avid fish eaters. The per capita consumption of fish (live weight) is about 18 kg (1979), just barely above the world average of about 12 kg. By comparison, Malaysian consumption is 43 kg per person and Japanese, 60 + kg per person. Even the lowest income groups in the Philippines consume more than 20 kg of fish annually per capita. Consequently, a well orchestrated selling and public relations program must be instituted in Canada.

The primary demand for fishery products is not yet established. It has not reached the status, for instance, of the dairy industry which was "sold" many years ago. The health conscious Canadian has known for many years the nutritional superiority of fishery products, but the lack of sufficiently convincing promotion and product quality have so far failed to significantly move the consumers. Interestingly enough, however, an increasing awareness of fish as a low calorie, high protein source is just now becoming evident in the quantity and quality of advertisements in current, popular, Canadian magazines.

The present infrastructure consists of marketers, not sellers. These marketers, however, can become sellers if they know they will receive goods of consistent quality on request and have back-up sales aids. In today's market, variability of product in both quality and supply is a significant problem. Sales aids, such as industry-wide promotion through "popularization" advertisements, new packaging and/or display techniques and general educational devices, such as recipes and innovative menus are required. If a good selling job is done, the existing marketing infrastructure will respond accordingly.

A well constructed sales plan is often missing in individual farms. In fact, the almost total attention paid to the early stages of production preclude most thoughts of selling the end product, particularly when time from start to harvest can be 3 years or longer. Equally lacking is North American recognition of aquaculture produce. The production of cultured fish products in the United States amounts to a mere 2% of their total fish output. In Canada, the contribution of cultured products compared to total output is even less. By comparison, cultured products in Asia account for over 15% of the total output. Conditions are changing rapidly, however, particularly since capture fisheries on a worldwide basis approach their limit. The opportunity and necessity of introducing cultured products to the market have never been more urgent.

Technology

Elements of technology must be carefully examined and weighted according to their importance and suitability. Such general elements as nutrition, disease control, seed production, larval rearing, grow-out, harvest techniques, and product quality are important.

However, even more important is the track record of the technologies within each of the above elements. Since aquaculture is experiencing a technology explosion, these track records are often not long enough, nor is the technology sufficiently widespread. New technology with meaningful pilot study results should be transferred in an orderly fashion and not in a "shot-gun" approach. The steady diffusion of a new technology is essential, and should be assisted with financial incentives, such as tax write-offs and cash concessions. The potential for aquaculture in North America has greatly increased during the past decade because of these technological achievements. This is even more evident in the Northern Hemisphere since technological sophistication is required for intensified systems.

North American commercial industries are now established in salmon net/pen culture and ocean ranching, abalone culture, prawn and shrimp culture, blue mussel and oyster culture, oyster hatcheries, catfish culture, and trout culture. Approaching production are such technologies in scallops, seaweeds, clams, and eel culture, although commercial operations of the foregoing do exist in other parts of the world.

In Canada, an excellent human resource pool is available with expertise in salmon and trout culture technologies, as well as in mollusc production. However, the technologies are still not sufficiently refined to be considered routine, which seriously impedes investment other than by high risk takers. As previously mentioned, disease prevention, quality control, and quality improvement are the major concerns in production and sales, but they require technological input in preventive medicine, system design, and genetics. Also required, in the case of quality improvement, are better methods of killing, dressing, preparing, storing, preserving, and displaying the end product.

Education

Important elements in education for aquaculturists focus more on experience, or lack of it, rather than on formal achievements. Currently, there is a surplus of well-qualified biologists ready to participate, but few of them have had any business experience. Engineering requirements in aquaculture are not large. Thus engineers are not attracted to the industry to the degree they are to oil, gas, and mining, for instance (present economic conditions aside). Also, business graduates are often discouraged from participating in aquaculture because of its low profile and attendant low wages. Without management showing some business background or training, passive investors view enterprise capability as being weak. Since lending institutions have an aversion to dealing with shaky management, this weakness must be eliminated.

The present training and educational infrastructure in Canada is well established and eminently capable of providing necessary support. Courses for the aquaculturist must be readily accessible. Adult training methodology has responded dramatically over the past decade to meet the requirements of distance learners. Such equipment as closed-circuit television, video cassettes, and tape recorders are now well established and accepted teaching aids. Many post secondary institutions provide mobile units for remote teaching. This educational infrastructure provides the system for offering quality extension courses in aquaculture.

Symposia, conferences, and exhibitions in aquaculture are now being offered all over the world. It is not difficult to find at least one major conference every month. What is difficult to find, however, is the money and time to attend.

Finance

Elements of financing that require in-depth consideration are capital requirements for construction, equipment, land and start-up inventory; personal equity; debt funding; taxation; forecasting; insurance; and incentives, such as employment grants, technology transfer concessions and tax deferrals or write-offs.

The present industrial infrastructure will permit an investor to estimate capital expenses of construction and equipment costs. Land costs are also readily available if land must be purchased. However, start-up inventory, such as eggs or fry, must be carefully coordinated with such things as site size, market projections, and trade credit, and is almost always calculated upon inadequate historical data. If, for instance, fry survival is low, or initial requirements are underestimated, the value of the crop when harvested may be insufficient to meet operating costs.

Perhaps the most common problem in any small venture is insufficient equity. Unfortunately, personal finances seldom match the entrepreneur's enthusiasm. That is not all bad, however. Canada's prosperity ultimately depends upon the small business sector to pioneer new fields and thus create jobs and generate new cash.

Business people in aquaculture are high risk takers. This has resulted in a new industry with more than its share of undercapitalized ventures. Reasonable debt financing is hampered by the industry's immaturity and inability to point to a proven track record with reliable costing information. The paucity of data on production costs alone prohibits reasonably accurate profit/loss and cash flow forecasting. After 2 or 3 years of operation, this data begins to accumulate, but is of little value when approaching a bank for a line of credit. Venture capital sources, banks, and other lending institutions will not assist aquaculture if useful proforma statements are not possible to prepare, if management capabilities are inadaequate, and if the status recognition of the industry is substandard.

Tax treatment is inconsistent with other forms of farming. In some areas of the Sales and Excise Tax Act, for instance, aquaculture is treated as neither farming nor fishing, and the preferential tax treatments afforded these two vocations are not available. Again, the problem is status, or, more aptly, nonstatus.

The industry requires financial assistance during the transfer of government developed technology. Philosophically, the assistance should not be viewed as a grant, but as a necessary cost to full implementation of the technology. Only at the private level will it truly mature and be cost effective.

DISCUSSION

The infrastructural support necessary to encourage investment in aquaculture must be directed to improve shortcomings affecting status, such as:

- — low priority
- — immaturity
- — low market demand
- — low interest
- — conflicting motives
- — generally high prices

Of the risks listed in Table 1, Management, Personnel, and Wastage are of greater concern to lending institutions and venture capital companies than to the entrepreneurial aquaculturist, while Technology and Politics appear to be of greater concern to the aquaculturist. This imbalance must be corrected, but the aquaculturist cannot expect the financial community to do the correcting.

Production data are scarce, and what little exists is proprietary, or so site specific as to be meaningless to a new enterprise. However, a concerted effort must be made by the industry to accumulate, document and share production operating cost data, if for no other reason than to establish bench marks against which each operation can measure itself. Proprietary data will always develop when the establishment matures. The industry is too fragile yet to be concerned about corporate secrets.

The ability to innovate with available equipment, to keep it functioning when repair facilities are virtually unobtainable, and to use it with versatility is the cornerstone of any successful business. If there ever is an industry that demands this capability, aquaculture is a prime candidate.

There is no infrastructural support that will assist in providing adequate operating cost information for forecasting. Currently, common sense and experience play the major role. At the preplanning stage of an aquaculture venture, however, experience may be in short supply. Nevertheless, there is a need to provide a checklist against which each potential farm can evaluate problem areas. A cross section of opinion on each problem area and its probability of occurrence would be an excellent first step. This would require soliciting opinions from present farm owners and management, perhaps through a Delphi approach.

Canadian aquaculturists should look to the diversification of crops, such as the polyculture of two or more compatible aquatic species, or the culture of compatible terrestrial organisms along with fish. Although polyculture represents a method of reducing production risks, it is the market that will dictate the species. The polyculture of finfish with oysters or clams is quite possible, as is the culture of two finfish species, such as trout with sturgeon. Polyculture is a well practiced art in other regions of the world. In fact, the highest production achieved from all forms of extensive culture comes from polyculture systems in Thailand.

Markets must dictate. Either the market already exists, or it must be created. Selling and promotional programs conducted at the national level by governments and associations, and enthusiastic participation at the local level by the individual aquaculturist will ensure a healthier market, thereby enhancing investor confidence.

Proven, reproducible technologies in nutrition as well as disease prevention and control are necessary, with culture systems and genetics of almost equal importance. In addition, quality control and quality improvement must be recognized as necessary precursors to successful sales programs. Research in these areas should be shared among industry, government, and higher education.

Clearly, the risks in aquaculture are high. Available information is inadequate and previous experience in most aspects is either short or completely lacking. Probabilities need to be reduced from perceptions to known outcomes, or from the subjective state to the objective state.

SUMMARY

Although the foregoing has touched on several points it would be useful to offer as a summary a list of high-risk problems in aquaculture about which an investor will be particularly concerned. The list is open-ended and is in no particular order of importance, since each investor will have different priorities.

1) Inadequate operating cost data
2) Poor industry status
3) Inadequate level of commitment to improved systems design
4) Noncommitment to preventive medicine and disease control
5) Tax inequality and disincentives
6) Almost total inattention to sales plans
7) Weak facility to continuous learning
8) Weak public relations
9) Production irregularity
10) Variable quality control
11) No quality improvement
12) Weak management
13) Short technology track record
14) Conflicting and confusing regulatory environment

The two planning areas, production and sales, are weak or lacking in informational sources or commitment, and the appropriate infrastructural support must be organized. Both technology and education need to be focused and strengthened, but the basic infrastructure is in place. If taxation incentives are forthcoming, financial commitment to aquaculture will develop as production, sales, technology, and education mature.

Further discussion must now lead to specific recommendations. Action must follow.

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REDUCTION OF RISKS IN CANADIAN AQUACULTURE THROUGH APPLICATION OF BIOLOGICAL RESEARCH

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ABSTRACT

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This paper describes how biology-related risks inherent in aquaculture can be avoided or reduced through application of appropriate technology. Although emphasis is on salmonid culture, the principles of risk reduction in relation to disease, nutrition, genetics, and physiology can be applied to other cultured animals. Some physical risks from low temperature and heavy seas are discussed briefly. Canadian research in the fields of disease, nutrition, genetics, and physiology is described in relation to the institutional arrangements for collecting data and disseminating information in the form of appropriate technology to the aquaculture industry. Examples are given to show not only how risks can be reduced or eliminated through application of biological technology but also how productivity can be greatly increased, thus decreasing financial risks. Serious risks remain, particularly from disease and inadequate nutritional quality. On the other hand, increased survival and greatly improved production are possible through new technology coming from nutrition research with special emphasis on diets for different life stages and environmental conditions, genetics research and selective breeding for more productive strains, and manipulation of the physiology through environmental control, resulting in increased productivity of cultured animals.

There is a special and continuing requirement for pilot-scale-demonstration farms for testing biological technology, together with an extension service to complete technology transfer. Vertical integration of aquaculture enterprises may help to reduce risks since all levels of operation (broodstock, hatchery, juvenile rearing, and production facilities food procurement, preparation and storage; harvesting and marketing) are largely, or entirely, under control of one company. The concept of cottage aquaculture may be possible through membership in cooperatives in which procurement, preparation and storage of food, maintenance of broodstock, juvenile production and processing, storage and marketing of the product are shared, thereby spreading the risks among many and eliminating some risks through corporate control.

INTRODUCTION

Aquaculture is acknowledged to be a high risk venture at best and these risks are greatest in the early stages of development. Salmonid aquaculture, which I intend to emphasize in this paper, is a new industry in Canada still facing many uncertainties owing to low production, competition from other countries, an incomplete infrastructure with respect to acquisition of broodstock, availability of appropriate food-stuff, marketing facilities and price structure, and an adequate system for development and provision of technological advice to the industry. In his development plan for Atlantic salmon aquaculture in the Maritimes, Anderson (1980) concluded that "... some of the more pressing constraints in an orderly development of aquaculture in the Maritimes tend to be political and administrative, rather than scientific and technical." This Conference is designed to address institutional rather than purely technical aspects of aquaculture. My assignment is to show how biology-related risks inherent in aquaculture can be minimized if appropriate technology is applied. Accordingly, I shall discuss the importance of the biological considerations, disease, nutrition, genetics and physiology, the need to conduct research in these areas, and the mechanisms required to transfer biological technology to the industry.

Much has been learned from study of the research and development institutions and the successful salmon farming industry in Norway. Although some of the technology developed in that country can be transferred directly to Canada, most practices have to be adapted to our peculiar environmental conditions (Saunders 1982). The Norwegian coast has numerous fjords and is sheltered by many islands, providing nearly unlimited locations where net pens can be moored with little or no danger from wind and heavy sea. Although the latitude is high (59–70°), the sea temperature is favorable for year-round salmon farming along much of the Norwegian west coast because of a northward-flowing branch of the Gulf Stream. Although there are many locations with adequate protection from wind and sea in Atlantic Canada, there are few locations with suitable winter temperature. Lethal temperature is reached nearly every winter in all areas except the southwestern Bay of Fundy. Sea Pool Fishery, which began salmonid rearing in Clam Bay, Nova Scotia, in the 1960s, discovered the risk of low winter sea temperature. Early plans to rear salmon and trout in tidal water were abandoned after test lots of fish were lost to super-cooling in a tidal estuary. This led to costly development and operation of an oil-heated water recycle system. It is safe to say that Sea Pool's lack of attention to the physical risk, low temperature, together with biological risks such as those related to disease, nutrition and physiology, and especially financial and plant management, led to the demise of this promising company. Lethal temperature presents a risk in SW Bay of Fundy and precludes overwinter cage rearing of salmonids in most other parts of the Atlantic provinces. During five winters since year-round operations began at the Marine Research Associates (Marine Products Ltd.) site at Lord's Cove, Deer Island, New Brunswick (Sutterlin et al. 1981), temperature has fallen to as low as 0°C. Lethal temperatures were reached and salmonids were killed at two Nova Scotia sites, St. Margarets Bay and Argyle, both on the SE coast. Aquaculture insurance may be available to operators in areas where loss to super-cooling occurs rarely but insurance companies are unlikely to offer coverage for high-risk areas.

Successful development of salmonid and other forms of aquaculture in Canada will be aided by efficient transfer of information and technology from domestic research effort, together with information gathered from research and production in other countries. In this paper, I describe research in the areas of disease, nutrition, genetics, and physiology in the context of reducing risk and/or improving production in Canadian aquaculture, with particular reference to salmonids. Emphasis is on the institutional approach to collecting scientific data and developing appropriate technology. Cases are made for development of experimental farms to test newly developed Canadian or foreign technology at production levels and for establishment of an extension service to aquaculturists, both comparable to similar institutions in agriculture.

DISEASE RISKS

Among the most serious risks to the viability of aquaculture are diseases and parasites. MacCrimmon (1974) concluded that until such time as fish disease problems are better understood, commercial aquaculture must remain a high-risk venture. Under balanced conditions in nature, most pathogens and parasites are held in check. Epizootics in nature are usually triggered by increased population size and other environmental shifts, sometimes man-made, which place the host species at a disadvantage. Mass culture of a single species removes interspecific competition and predation but such reduced stress is often replaced by behavioral stress from unaccustomed proximity to members of the same species, resulting in physiological changes making the animals less resistant to infection. Culture in less than optimal conditions with respect to temperature, dissolved oxygen content, current velocity, and accumulation of metabolic waste products, compounds the stress situation. Such conditions invite disease. Once introduced in a stressed population, pathogens easily produce an outbreak of serious proportions. The cultured animals may be even more vulnerable to pathogens to which they are not usually exposed but which thrive under the culture conditions. The simple solution to stress-related diseases is to maintain the cultured animals under optimum environmental conditions and reduce stress of all kinds. This is more easily said than done. We can provide optimum conditions so as to produce best growth and production and to minimize some forms of stress. However, most animals in mass culture will be under some stress.

The most obvious way to reduce the risk of disease is to start with disease-free animals and to allow no pathogens to enter the population through newly introduced animals, the water or food supply, or the workers and tools they use. Although theoretically possible, maintaining pathogen-free animal stocks is difficult, especially when they are moved from hatcheries to grow-out facilities such as sea cages where control over introduction of water-born pathogens is virtually impossible.

Realistically, aquaculturists should expect to face disease outbreaks and be prepared to cope with them. Cultured stock should be checked periodically and any dead animals removed for examination. If disease organisms are found in association with dead or sickly animals, the latter should be destroyed. Isolation measures should be started, paying particular attention to effluent from the diseased tank or pond and tools that may be contaminated; no animals should be moved to, or from, the contaminated group. Medication applied soon enough can often reduce losses but will rarely eliminate the causative organisms which continue at low levels of infection until appropriate conditions for their proliferation develop again. There is also a danger of the development of drug resistance with haphazard and frequent therapeutic treatment. Extreme measures include destruction of the diseased stock and sterilization of the tank and tools used.

Some notable outbreaks of disease in eastern Canada were Malpeque disease in oysters of Prince Edward Island, Nova Scotia, and New Brunswick and enteric red mouth (ERM) in salmonids being reared in Bras d'Or Lake by Cape Breton Marine Farming (CBMF). Diseased osyters are believed to have been brought in 1914 to P.E.I. from New England. The disease later spread to Nova Scotia and New Brunswick. It has taken many years to repopulate the affected beds with oysters resistant to the disease. ERM disease was introduced with a shipment of rainbow trout from the U.S. mid-west in 1976. The supposedly disease-free trout developed symptoms after arrival in Cape Breton and the donor stocks subsequently developed symptoms. Over 300 000 rainbow trout, including CBMF broodstock which were contaminated, were destroyed to prevent spread of the infection. This extreme measure was apparently successful since the causative organism has not again been found in the Bras d'Or Lake area. An outbreak of furunculosis developed in adjacent ponds of brook trout and Atlantic salmon being reared by the New Brunswick Department of Natural Resources in thermal effluent in association with the Grand Lake coal-fired electrical power station, Minto, N.B. This necessitated destruction of all fish at the site. The ponds were sterilized and the fish replaced with others free of furunculosis; no subsequent outbreak of the disease has occurred. The fatal disease, gaffkemia, is responsible for continuing heavy losses of naturally produced lobsters held at high densities in pounds; some outbreaks of disease have inflicted heavy financial losses on pound operators. Risks from gaffkemia are greatest where many lobsters are held under crowded conditions, if circulation and water renewal are inadequate and when temperature is relatively high. Gaffkemia could also be a serious threat to lobsters reared in aquaculture. Diseased stocks of Pacific salmonids undoubtedly contributed to the difficulties encountered by Sea Pool Fisheries, and these, together with facility and financial mismanagement and nutrition inadequacies, contributed to the demise of the venture.

In recognition of the threat of diseases to salmonid aquaculture operations in Canada, a set of National Fish Health Protection Regulations (FHPR) (Department of Fisheries and the Environment 1977) was enacted in 1977. Local Fish Health Officers for provinces or regions are responsible for enforcement of the regulations through an import permit system that controls interprovincial movement of cultured, live salmonids, their eggs, and dead products. These permits may be issued on the basis of a Fish Health Certificate, acquired by an exporting facility as a result of a series of inspections of their fish stocks, using designated protocols, over a 2-yr period. These inspections are carried out by Fish Health Units in Nanaimo, Winnipeg, and Halifax, which provide diagnostic laboratory and field liaison services. Within each of the three Maritime Provinces, there are in effect policy guidelines for interwatershed transfers of salmonid fishes with respect to certain specified diseases, and these too are implemented by the Fish Health Unit.

In addition to implementing the FHPR, the Scotia–Fundy Fish Health Unit, like others in Canada, designs and regulates quarantine facilities for approved imports of aquatic plants and animals (particularly important when these are nonindigenous), advises on fish health matters relating to salmonids in Federal Fish Culture Stations and those in natural waters of the Region, and is responsible for investigating kills among aquatic animals in nature. In the Maritime Provinces, a particular responsibility is recognized for the provision of service to the lobster industry; the loss to disease in large holding operations can be disastrous. The Fish Health Unit provides a free diagnostic and counselling service to other government agencies and private industry. In the Scotia–Fundy Region, there is an Aquaculture Coordinator whose duties, in addition to those dealing with permits for aquaculture operators, include acting as a focal point for aquaculture enquiries and providing extension service with particular reference to fish health.

Awareness and interest in the risk of diseases and parasites of aquatic animals are reflected in the level of research by government, university, and private interests. The Federal Fish Health Units are, in most cases, associated with research on bacterial and viral pathogens as well as metazoan parasites. The Disease and Nutrition Section at the Halifax Laboratory has sponsored seven annual Fish Health Workshops at which results of disease research conducted at the Laboratory as well as at other institutions in eastern Canada have been presented. These workshops have provided fish and shellfish producers with an opportunity to present their problems and to learn how science and technology can improve their production. Universities are responding to the growing needs of developing aquaculture in Canada by training students in microbiology, virology, and parasitology. There are Fish Health Programs in Canada's three veterinary colleges, Guelph, St. Hyacinthe, and Saskatoon. The University of Guelph is particularly active in research on nutrition, genetics, and diseases as they pertain to industrial production of fishes. Connaught Laboratories have recently tested and are marketing a vaccine against "vibriosis," a serious and common disease of bacterial origin, affecting cultured salmonids in sea water. It has been proposed that an Atlantic Regional Veterinary College, to be established in the Maritimes, have facilities for diagnostic services, development and testing of vaccines, and an extension service to regional aquaculture operations.

NUTRITIONAL CONCERNS

Research on disease and nutrition is often conducted at the same institution and sometimes by a single team. The Fish Health Units in several laboratories of the Department of Fisheries and Oceans reflect this close association since disease is frequently associated with nutritional inadequacy. Pritchard (1974) listed disease control and nutrition as highest priority research topics as a basis for reducing risks in Canadian aquaculture. Although great strides have been made in both areas, much more research and development needs to be done. The nutrient requirements of salmonids in fresh water are quite well known, whereas those from the marine stages are just beginning to be known; lobster nutrition is less well understood.

The nutritional approach, like genetic improvement, may not only reduce risks but, on the positive side, also improve production efficiency by promoting faster growth, a superior product and better feed conversion efficiency. Food represents the largest cost item in production of salmonids.

Each cultured species has specific nutritional requirements in respect to the indispensable amino acids. These, with a number of dispensable amino acids, make up the protein portion of the diet which together with lipids, carbohydrates, trace minerals, and vitamins comprise production diets. Proteins are the most expensive dietary component; they are used for growth and must be present at the appropriate level in relation to other dietary requirements to promote health and efficient growth. Lipids and carbohydrates are important as energy sources for activities other than growth. Proteins are also available as energy sources but can be spared by lipids and carbohydrates for the more important growth function. Some lipid components, the omega-3-type fatty acids, are essential for health and growth. Dietary vitamins and minerals are also essential. Salmonids are exceptional in their efficient conversion of food to a high-priced protein; dietary formulations, and feeding strategies should take advantage of this attribute.

There are not only special nutritional requirements for each species but also changing requirements at different life stages and under different environmental conditions, i.e. for juveniles, grow-out stage and broodstock as well as for culture in fresh or salt water. With further refinement, nutritional requirements can be considered for animals of varying physiological condition and genetic background, sex, and previous nutritional history. The special nutritional requirements of salmonids in fresh and salt water are being considered. Appropriate food consistency and particle size can minimize wastage. Pigments are added to salmonid food to produce an attractive flesh color.

Nutritional research at the University of Guelph and the Ontario Ministry of Natural Resources has concentrated on special diets for rainbow trout, most of which are cultured in relatively cold ground water. The Fish Nutrition Research Group at the West Vancouver Laboratory of the Department of Fisheries and Oceans conducts research on salmonid diet formulation and use of thyroid and steroid (sex) hormones to enhance growth rate. Research at the Halifax Laboratory includes nutritional requirements of lobsters and formulation of diets for their culture. Current investigation is on calcium metabolism in relation to the molt cycle and metabolic patterns of eye-stalk ablated and normal lobsters. Other invertebrate nutrition studies are emphasizing algal species selection in oyster larvae and manipulation of algal composition for best survival and growth. Salmonid nutrition research at the Halifax Laboratory has emphasized juvenile production and is aimed at maintaining proper health of salmonids in the Federal hatcheries of the Maritimes. The Halifax Nutrition Project uses analytical and biological techniques to characterize nutritional deficiencies in cultured and wild fishes. Experiments have shown a nutritional link to bacterial kidney disease. There is a need to define nutritional requirements of broodstock to assure normal maturation and viability of sex products.

Fish and livestock feeds are referred to as open or closed formulae. The composition of closed-formula feeds is proprietary information of manufacturers. Open-formula feeds have been developed for rainbow trout by the University of Guelph and for Pacific and Atlantic salmon by the Department of Fisheries and Oceans' laboratories in Vancouver and Halifax, respectively. Using open formulae, manufacturing companies prepare feed according to specifications as to quality of fish meal, content of antioxidant, vitamins, and minerals as well as total protein, lipid and carbohydrate composition. This is in contrast with the products of some large feed manufacturers, using closed formulae, which respond to changing availability and price of ingredients, sometimes to the detriment of product quality.

The FAO Technical Conference on Aquaculture, Kyoto, 1976, the World Symposium on Finfish Nutrition and Finfish Technology, Hamburg, 1978, and the World Conference on Aquaculture and International Aquaculture Trade Show, Venice, 1981, emphasize the importance of nutrition research and its contribution to developing aquaculture. There is an extensive literature on nutritional requirements of animals used in aquaculture. Halver (1982), Ketola (1982), Watanabe (1982), and Castell et al. (1983) have recently provided comprehensive reviews. There is a special and continuing requirement for pilot-scale operations for testing feed formulations at production levels. Although a successful feed formulation has been developed for production of Atlantic salmon in sea cages, there is some uncertainty about the wisdom of altering proportions of protein, lipid, and carbohydrate, or changing sources of these components because of cost or availability. More research and development work is needed on cost-effective diets. Experimental fish farms, together with an extension service, should keep fish farmers advised as to safe and effective formulations of wet feed mixtures prepared by each operator or by cooperatives. Norwegian and Scottish salmonid farmers are using more dry, pelleted feeds for convenience and cost reduction. It is likely, however, that the salmon farming industry in Atlantic Canada will remain smaller than those European industries and that locally prepared, wet feed will continue to be used because ingredients are available and often inexpensive.

IMPROVED PRODUCTION THROUGH GENETIC MANIPULATION

One of the more promising ways to reduce economic risks in salmonid aquaculture, a necessity in view of the severe competition beginning to come from Norwegian-cultured salmon, is to grow only those fish with superior production characteristics such as low age at smolting, rapid growth in sea cages and late age at maturity. Such fish can be developed through appropriate choice of wild stock and subsequent manipulation of their genetic makeup. There have been three stages in the progression of the salmonid aquaculture industry in S.W. Bay of Fundy: choosing most promising species; finding the best wild stocks; and applying the science of genetics to develop strains with superior production traits. We have considered Atlantic and pink salmon and rainbow trout. Atlantic salmon are the most attractive of the three because they are reasonably easy to grow, they reach a large size and bring a high price. Norwegian geneticists have demonstrated during production trials with first-generation, hatchery-reared Atlantic salmon from wild parents from a number of rivers that there are two to threefold differences in size attained after 2 yr in sea cages (Gjedrem 1976), and that age at sexual maturity (the grilse vs larger salmon phenomenon) varies greatly among the many river stocks tested (Naevdal 1981). In the Salmon Genetics Research Program (SGRP) at the North American Salmon Research Center (NASRC), we have begun to screen wild stocks for the most promising candidates for genetic selection and development of special strains with superior production traits. To make their point that genetic expertise must be used to achieve maximum production from aquaculture candidates, the panel members of the session on Genetics and Genetic Improvement in Aquaculture at the FAO Technical Conference on Aquaculture at Kyoto (Anon. 1976) said "... with only few exceptions, that aquaculturists are using wild, completely undomesticated organisms, a situation comparable to using jungle fowl to run a modern poultry (farm)."

The theory of fish breeding is available from the science of poultry and livestock genetics. Domestication presupposes that the genetic makeup of a species is responsive to the environment. Wild aquaculture candidates are brought into hatcheries and their progeny are reared under culture conditions which are immediately different from nature where selection pressures tend to eliminate all but the most vigorous and those best adapted to their environment. If the culture process is successful, the genetic makeup will have changed and the animal is said to be domesticated. Aquaculture geneticists have the task of manipulating genetic change during and after domestication in such a way that the newly cultivated animal is enriched in respect to production traits.

The procedure is to bring wild stocks into the laboratory or hatchery and screen them for best prospects of domestication and then, depending on the principal type of genetic variance, i.e. additive or dominant, breeding should proceed employing selection or hybridization, respectively, to maximize each trait. It is important to take account of environmental effects which can result in vastly different phenotypes in animals of the same strain but reared in different environments. A topical example is age and size at sexual maturity in Atlantic salmon. Sea-ranched Atlantic salmon from a particular hatchery-reared strain gave grilse to larger salmon in a ratio of ca. 1.7:1 through sea ranching (i.e. release to migrate to and from the sea) while their cage-reared counterparts gave a much lower incidence (0.01:1) of grilse (Saunders et al. 1983). Together with any selection or hybridization scheme, it is important that unselected control populations be maintained as a basis for measuring gain during successive breeding generations as distinct from gains resulting from changes (improvements) in the environment.

Any aquaculture operation which rears and spawns broodstock has an *ipso facto* genetics program. Such aquaculturists should consider not only the expected gains and costs from a controlled mating program but also any potential losses from a haphazard breeding scheme. For example, a mating scheme using only the largest, most attractive animals without considering other traits and pedigrees of individuals could result in a rapid accumulation of inbreeding with subsequent deterioration in performance. In the early stages of broodstock management, emphasis should be on obtaining and maintaining a sufficiently diverse gene pool. This is a necessary first step to provide the genetic diversity required to implement a selection program.

In addition to traditional selective breeding and production of intra- and interspecific hybrids, geneticists are developing techniques to produce unisex populations. All-female salmonid populations are produced by feeding male sex hormone (testosterone) to early feeding fry. This results in "genetic" females becoming functional males which are then bred with normal females. The resulting progeny are all female. Manipulation of sex is also done by inducing polyploidy (multiple sets of chromosomes) and gynogenesis (all female production), both resulting from chemical and physical shocks applied either to the eggs and sperm separately or to newly fertilized eggs. These procedures are used to promote increased production through faster growth, later maturity or sterility.

Norwegian aquaculture geneticists have progressed well beyond the stage of screening wild stocks and are now comparing full-sib groups within strains and are progressing to the third stage employing selection and hybridization to maximize certain production traits. In the SGRP, we have also compared salmon of different river origin and have found striking differences in age at maturity between two strains. It was by serendipity that we first started using two strains of salmon which seem to represent the extremes in the important production trait, age and size at sexual maturity. It is imperative that we screen salmon from many wild stocks as a basis for selection and/or hybridization. We annually tag representatives of about 100 full-sib (family) groups of salmon to maintain permanent identity and are collecting data on survival, age and size at maturity from sea-ranched and cage-reared individuals representing these families. Emphasis in the Program is on development of strains with appropriate traits for sea ranching. Although one of the Program's objectives is to develop strains for cage rearing, we have not been able to move in this direction because we lack sufficient personnel to undertake this as well as the selection program for sea ranching. However, the SGRP has made good progress with production of unisex (female) or sterile populations which offer promise in cage culture because these either mature later or not at all, both attractive from the point of view of maximizing production.

A major constraint in the infrastructure for R&D in salmonid cage culture in Atlantic Canada is the lack of an experimental sea-cage facility at which to conduct pilot-scale projects in order to test technical and economic viability of the techniques for commercial application. There is a facility at the Pacific Biological Station fulfilling many of the requirements listed for such an R&D facility.

Across Canada there are a number of genetics research activities in support of aquaculture. Estimates of heritability of growth rate in coho salmon are being conducted in an accelerated rearing mode in the experimental fish farm at the Pacific Biological Station, Nanaimo, B.C. Possible changes in gene frequency are being measured in hatchery stocks of chum salmon in comparison with natural donor populations in Tlupana Inlet. Genetic research at the Freshwater Institute, Winnipeg, Manitoba, is aimed at developing strains of rainbow trout and Arctic char better suited for commercial culture. Interstrain comparisons, heritability estimates, and estimates of genotype-environment interaction have been made for rainbow trout in extensive culture operations and are being made for Arctic char and rainbow trout in intensive aquaculture systems using waste heat. Production of all female lines of Pacific salmon through hormone treatment is under way at the West Vancouver Laboratory, West Vancouver, B.C. Genetics research in the Ontario Ministry of Natural Resources is aimed at development of a system of genetic markers for important cultured and wild fish stocks. Electrophoretic, cytological, morphological, and ecological methods are being used to distinguish among stocks of Ontario game fishes. Researchers at the University of Guelph have considered genetic aspects of rainbow trout production in low temperature ground water and relative production of brook, rainbow, and lake trout and brook trout × lake trout hybrids (splake) under different temperature regimes. Researchers at the Marine Science Research Laboratory of Memorial University of Newfoundland are studying heritability and early expression of ovarian recruitment processes in anadromous and landlocked forms of Atlantic salmon and chromosome triploidy induced by heat shock and hydrostatic pressures. Genetics research at the Marine Ecology Laboratory, Dartmouth, Nova Scotia, emphasizes genetic and environmental influences on production of the blue mussel to provide measures of the potential for selective breeding. Genetic influences on growth rate and resistance to mortality at various life stages are being studied. Researchers at Dalhousie University, Halifax, Nova Scotia, are studying genetic aspects of European and American oyster production with particular emphasis on broodstock management and prevention of inbreeding through broodstock management and enhancement with new stocks. The goal is to produce through selective breeding strains of oysters adapted to the Canadian Maritime environment.

PHYSIOLOGICAL CONSIDERATIONS IN RISK REDUCTION

Manipulation of physiology through environmental control together with nutritional quality and quantity are important considerations in production of aquatic animals. Three aspects of physiology which directly affect fish growth and production and which are amenable to environmental control are energetics, smolt development, and sexual maturation. Canadian expertise is well established in these areas of research and represents an important component of the infrastructure in support of developing aquaculture.

Beamish et al. (1975), Brett and Groves (1979), and Cho et al. (1982) review their own extensive research and other experiments designed to increase our understanding of the complicated physiological processes involved with intake of energy in the form of food and its utilization for metabolism and growth. In its simplest form, this process, referred to as energetics, addresses the amount of energy retained for growth and reproduction in comparison with that lost as heat or excreted as urine and feces. The dietary composition (protein, lipid and carbohydrate) determines to a large extent the partition between use as fuels and retention as new tissue (growth).

Aside from dietary composition, three controllable environmental factors, fish size and developmental stage, dietary composition, and water temperature largely determine growth rate and feed efficiency of aquatic animals. Donaldson et al. (1979) and Higgs et al. (1982) review the use of various hormones to enhance the growth of fishes. Manipulation of fish growth through control of temperature, population density, day length (photoperiod), oxygen content, and salinity, as well as dietary quality and quantity, affect production of cultured fishes and other aquatic animals at all stages from juveniles to harvest size. Rather than being considered as a risk, control of growth and production should be perceived as an opportunity to maximize yield and to minimize cost. The need for efficient production including high feed conversion efficiency is emphasized by the generalization that feed accounts for about half the cost of salmonid production.

Salmonid aquaculturists have recognized problems and attendant risks associated with smoltification, the process whereby a salmon prepares physiologically and behaviorally for the transition between its freshwater life in a nursery stream and its wide ranging growth and maturation phase in the sea. Wedemeyer et al. (1980) discuss smolt quality and some environmental factors which affect the smolting process and, subsequently, early marine survival and performance. Problems arise with the quality of smolts produced in hatcheries; environmental manipulation used to speed growth and development sometimes deviates from those conditions required to trigger and sustain the complex physiological changes involved in smoltification. West Coast U.S. and Canadian salmonid physiologists have addressed a serious problem in the quality of smolts supplied through aquaculture and have held a series of workshops to consider the physiological bases for sometimes poor survival, stunting and untoward sexual maturation of reared smolts in sea cages and those released to migrate to and from the North Pacific. In 1981, there was an international symposium to address problems and to exchange information among physiologists from Europe, North America, and Japan working on smoltification in Pacific and Atlantic salmon. A committee within the organization of the European Economic Community is addressing Atlantic salmon smolt quality as a suspected major factor in the success of sea ranching which is seen in several European countries as a promising aquaculture strategy. The results of the considerable research being directed to a better understanding of smoltification are being applied to Canadian smolt rearing operations with benefits accruing to salmon farming enterprises. Pacific and Atlantic salmon smolts grown under appropriate environmental conditions in respect to temperature and photoperiod can be expected to survive transfer to sea water and to grow as well as their naturally produced counterparts. However, the time required and the cost of rearing coho and Atlantic salmon to the smolt stage have necessitated accelerated rearing regimes. Heated water is used to advance hatching and early growth so that the time to produce smolts is half or less than that required in nature. The elevated temperature and lengthened photoperiod regimes used to achieve such growth are not necessarily compatible with smoltification and the resulting fish, though having the appearance of smolts, often have low rates of survival and grow poorly after entering sea water. Because of the current shortage of Atlantic salmon smolts for aquaculture in Atlantic Canada, there is much interest in producing them by using thermal effluent from power plants. This practice is attractive and effective provided appropriate thermal limits are not exceeded in the spring as smoltification climaxes. Photoperiod should not deviate from the local, natural one. Smolt producers should guarantee their output not only for immediate survival after acclimation to sea water but also for growth performance for the first summer. Aquaculturists purchasing smolts should minimize their risks by insisting that smolts exceed a minimum acceptable size. Although Atlantic salmon at the peak of smolt status can withstand direct transfer to sea water, further risks can be avoided by acclimating them to sea water. This practice will help to identify those that do not have smolt status and will reduce stress in good smolts. A more subtle requirement of salmonid smolts is that they perform well, i.e. grow rapidly, during the months following entry to sea water. It is possible to produce smolt-sized and smolt-appearing fish which survive in sea water but do not grow and perform as smolts in other respects. Such incomplete smolt status may be the result of inappropriate temperature-photoperiod treatment during winter–spring when smoltification normally proceeds. Several authors in the May 1980 Symposium on Aquaculture in Heated Effluents and Recirculation Systems (Tiews 1981) reported on temperature-photoperiod regimes used for production of Atlantic salmon smolts. Isaksson (1983) describes past unsuccessful and recent successful attempts to produce 1 + yr smolts by using geothermal water in Iceland. Canadian research on salmonid smolting is being conducted at the Biological Stations at St. Andrews, N.B., and Nanaimo, B.C., and as well, at the University of Prince Edward Island.

One of the greatest uncertainties in the production of cage-reared Atlantic salmon is age and size at sexual maturity. The production of one-sea-winter salmon or grilse plagues the established salmon farming industries in Norway, Scotland, and Ireland. Although genetic origin has a clear influence on age at maturity, the environment also plays a major role. Smolt size, nutrition and feeding regimes, and sea temperature likely interact with genetics in determining age at maturity. Evidence is accumulating that older, larger smolts are more likely to produce grilse and that mild winter sea temperature also favors grilse production. Fortunately, the risk of grilse production is reduced in Atlantic Canada since winter sea temperatures are very low. Mild winter sea temperatures in France and Ireland are probably responsible for most cage-reared Atlantic salmon in those countries maturing as grilse.

Research on age at maturity is actively pursued in Atlantic salmon producing countries because this factor, which can greatly influence production levels, can spell the difference between profit and loss in aquaculture ventures.

Physiologists at the Marine Science Research Laboratory, Memorial University of Newfoundland, are studying techniques for synchronizing and altering spawning time in salmonids. A coordinated effort in the Salmon Genetics Research Program at the North American Salmon Research Center and the Biological Station, St. Andrews, New Brunswick, is being made to increase our understanding of genetic and environmental control of age at maturity in Atlantic salmon and of hormonal and environmental manipulation of spawning time. Biochemical studies at Dalhousie University and the St. Andrews Biological Station are investigating temperature-sensitive responses to estrogen in vitellogenin production by the liver. Saunders et al. (1983) have recently reported on the influence of winter sea temperature on age at sexual maturation of Atlantic salmon. The Canadian Atlantic Fisheries Scientific Advisory Committee is planning a workshop on genetic and environmental factors determining age at maturity of Atlantic salmon. We can be optimistic that the uncertainties of production levels owing to age at maturity will be reduced as we learn more about genetic and environmental influence on maturation.

Physiological research on growth and reproduction of lobsters under culture conditions is conducted at the St. Andrews Biological Station. This research stresses effects of temperature on growth and of temperature and photoperiod on sexual maturation. A breeding–hatching–rearing facility is being operated for studies of cost-effective hatching and rearing methods. This research, aimed largely at assessing biological and environmental factors as they affect naturally produced lobsters and management of this resource, has a direct application in aquaculture. The technology produced through these studies is available to lobster holding operations and will provide much of the basis for full-scale lobster hatching–rearing–production operations, once they become economically feasible. A lobster holding–rearing operation, Marine Lobster Farms (MLF), has been underway for several years on Prince Edward Island. MLF conducts experiments on filtration and water treatment systems and closed systems for holding lobsters, and has developed closed system holding systems for larval and small juvenile lobsters. A deep tank concept for high density holding of lobsters has been tested.

DISCUSSION

One of the chief recommendations coming from the FAO Aquaculture Conference in Kyoto was "... that governments and financing agencies support the establishment of suitable pilot-scale or model projects in order to test the technical and economic viability of the techniques for commercial application." I endorse this recommendation, particularly as it applies to the development of Atlantic salmon sea-cage culture and sea ranching in Atlantic Canada. Research in the four biological areas I have discussed, disease, nutrition, genetics and physiology, can be conducted largely in the laboratory or in hatcheries. However, in nearly every case where I have been involved, the need arises to take the experiments to a fish farm not only to test preliminary conclusions at production levels but also under environmental conditions hardly attainable in the laboratory. Through contract and sometimes barter arrangements, we have reared experimental lots of salmon at local sea-cage sites. These arrangements often result in compromise on the parts of both the fish farmer and researcher because scientific research and commercial production are rarely compatible. The Norwegians, who are about 15 yr ahead of us in sea-cage culture of salmon, appreciated this compromise early and developed pilot sea farms. Both the Institute of Marine Research and the Agricultural University of Norway have extensive hatchery-rearing stations for genetics studies and sea-cage facilities for rearing smolts to adults under production conditions (Edwards 1978). An experimental sea farm would have facilities for rearing large lots of smolts for genetics studies to produce data on survival, growth, and maturation, as well as providing broodstock. Such facilities are required to achieve the objectives of the SGRP, production of separate strains with appropriate traits for sea ranching and for commercial culture in sea cages. Testing of sex-reversed and mono-sex lines of salmonids must be done at production levels. Although much of the research on disease and nutrition can be carried out in the laboratory, the large-cage facility is a necessary adjunct for feeding trials at production levels and for field evaluation of vaccines. Sea-cage facilities provide a unique opportunity to study the marine phase of the salmon's life cycle, previously little known because salmon are rarely accessible after migrating to sea. It is especially important to evaluate smolt performance, as influenced by freshwater rearing regimes, in respect to early survival, growth performance, and age and size at maturation. Experimental, demonstration farms are an important aspect of agriculture. Specialized, experimental, aquaculture facilities for production of shellfish, finfish, and plants, together with an extension service to the aquaculture industry, are as essential in aquaculture as they are in agriculture.

Finally, vertical integration can play an important role in reduction of risks of all kinds, including those biological factors, disease, nutrition, genetics and physiology, as well as those risks related to economics. Vertical integration confers protection from a number of risks since all levels of an aquaculture enterprise (broodstock, hatchery, juvenile rearing, production facilities, food procurement, manufacture and storage, harvesting and marketing) are largely or entirely under control of one company. Having control of broodstock is an obvious advantage in view of genetic improvement and maintenance of disease-free status. Proprietary control of genetic lines or strains of poultry and livestock confers much advantage to owners. Reliance on outside sources of food can be dangerous in respect to uniform quality and reliability of supply. The quality of seedstock in respect to size and physiological condition can be controlled in a vertically integrated company. Two successful salmonid aquaculture companies, Mowi in Norway and Unilever in Scotland, are vertically integrated, not only maintaining a large degree of self-sufficiency in their own operations but also providing some goods and services to smaller operators.

Aquaculture will ultimately become big business, like agriculture. In the short term, responsibility for research and development will be mainly the responsibility of government agencies. Much of the appropriate infrastructure has already been developed to provide the research and development; expansion in some areas and perhaps redirection of efforts will be required as the industry develops and new problems are discovered. Development of long-range plans with sufficient flexibility to avoid disruption to the industry through inability to respond to emergency situations may be the most important role of government agencies. Whether or not salmonid aquaculture can succeed as a "cottage" industry in eastern Canada remains to be seen. It is likely that a number of large, vertically integrated units, perhaps with support from government, will be required to pioneer and stabilize the industry. It would appear, nevertheless, from the Norwegian experience that both large and small operations could be successful. Norway has developed smolt production, food making, and fish processing facilities which serve a number of small operators. This allows the existence of small operations without the need for large capital expenditures. A combination of traditional fishing operations and small aquaculture enterprises may prove to be feasible. If salmonid aquaculture in eastern Canada is to succeed, it must develop efficient smolt production facilities to replace the present inadequate supply from government hatcheries. It would be unfortunate if the original idea of "cottage" salmonid aquaculture cannot flourish in eastern Canada owing to the multitude of risks. Some level of independence may be possible through cooperatives in which the procurement, preparation, and storage of food, maintenance of broodstock, juvenile production, and processing, storage, and marketing of the product can be shared, thus spreading risks among many and eliminating some risks through corporate control.

As in the agriculture industry, aquaculture will require development of a government-sponsored extension service with trained people working closely with aquaculturists to communicate technology from domestic and foreign research and, equally as important, to provide feedback information and problems as guides for research in the laboratory and testing of technology at experimental production facilities.

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PLANNING FOR AQUACULTURE DEVELOPMENT IN CANADA: A MARITIMES PERSPECTIVE

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ABSTRACT

COOK, R. H., AND R. E. DRINNAN. 1984. Planning for aquaculture development in Canada: A Maritimes perspective, p. 78–87. *In* G. I. Pritchard [ed.] Proceedings of the National Aquaculture Conference — strategies for aquaculture development in Canada. Can. Spec. Publ. Fish. Aquat. Sci. 75.

The nature, scope, and potential of aquaculture are considered in light of its present status in Canada. The interactions between and within government agencies and with the aquaculturist are diverse and complex and improved methods are required to resolve the conflicts that arise. An analysis of the constraints to aquaculture development indicates the need for improved national and regional planning as well as the requirement for specific guidelines and policies respecting aquaculture development. The priority elements of planning for aquaculture are identified and the establishment of Aquaculture Resource Planning Boards is proposed to facilitate the planning process.

INTRODUCTION

Aquaculture, as a socioeconomic strategy, is coming of age in Canada. From precarious beginnings of boom and bust, of having to rely on inadequate technologies, of variable and generally insufficient investment capital, and an overriding awareness of the competition from the traditional fisheries, the aquaculture industry is making steady progress in its development. We gain confidence from the economic success of certain aquacultural practices in northern European countries, for example with sea cage-reared Atlantic salmon in Norway and Scotland, and are encouraged to initiate appropriate parallel projects in Canada.

Slowly, the inventory of aquaculturally reared species is increasing in Canada; steadily, aquaculture production, and the value of this production, are becoming a significant economic fact within the fisheries sector. Unfortunately, the progress made to date has not usually been the result of long-range governmental planning or assistance. The advances made to date have often been the result of ad hoc arrangements between producers and individuals in various governmental agencies. Without a mechanism to address the information needs and to coordinate the regulatory requirements of the industry, planning so that aquaculture can achieve its full economic potential will continue to be hampered. More formal recognition of the social and economic potential of aquaculture is long overdue. A suitable framework for the industry is required to safeguard the interests of the aquaculturist and to coordinate the future planning and support of the industry on an intergovernmental basis. Some of the requirements of coordinated planning and development mechanisms are discussed in the following sections.

Though it is intended that the general principles, philosophy and recommendations stated or developed will have wide national validity and relevance, there will undoubtedly emerge an emphasis on concerns of importance to the Maritimes or Atlantic coast generally. Examples cited tend to be drawn from this area, and proposed remedies or desirable actions are perhaps too specifically adapted to the social, legal, geographic, and historic perspectives there. This results from the authors' past experience and greater familiarity with the Atlantic industry and area and not from any conception of their greater importance.

Some appreciation of the essential nature, scope, and potential of aquaculture, in the Canadian context, is a primary requisite in any discussion of processes and strategies appropriate to developing an effective and efficient route to the achievement of the optimum potential.

THE NATURE, SCOPE, AND POTENTIAL OF AQUACULTURE

Many definitions of aquaculture have been developed and are available in the literature. Most reflect the specific and usually relatively circumscribed requirements of the particular context and are not easily transferable to others. From participion in developing such definitions for a diversity of national and international purposes, it is suggested that a broad general definition is usually most appropriate, modified and restricted, as appropriate, to specific requirements.

For present purposes, aquaculture includes any activity which produces aquatic organisms and involves the application of animal or plant husbandry at some stage in the life cycle. This includes a wide range of levels of sophistication and human involvement, from the most intensive, such as the rearing of fish in a closely controlled recirculated water system, to the extensive techniques of sea ranching where hatchery-reared animals are released to the natural environment for growth and recaptured on returning to spawn, or techniques of molluscan culture where provision of a substrate and protection from predators and detrimental environmental factors are the only human interventions. In the following we are principally concerned with commercial profit-oriented activities carried out by the private sector. Other classes of aquaculture in the public sector, e.g. salmonid rearing for stock enhancement purposes, or such activities as hobby, even home aquarium rearing, may have relevance to or impact upon private commercial culture and will be considered, as appropriate.

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Aquaculture operations have some common features which are responsible for many of the complexities inevitable in their establishment, continued existence, and development:

- They use a common property resource subject to a number of legal controls, diverse jurisdictions and a common public assumption of free access, namely water, be it from the ground or a stream, estuary or the ocean.
- They employ native species, usually of high unit value and demand, which are the traditional target of commercial or sport fisheries, or exotic, introduced species. Each poses special problems and potential threats, real or perceived, to the social and ecological status quo.
- With the exception of a very few well established culture practices, aquaculture is a new concept often associated with "outside business" interests and viewed with suspicion by a largely conservative rural population, jealous of its traditional rights.

Aquaculture must be accepted as a technique of food production, alternative and complementary to the traditional capture fisheries, in many ways parallel to agriculture but with the important added dimension which the use of water as an essential medium brings to it. It is this dependency on the water resource which greatly increases the jurisdictional uncertainties associated with aquacultural developments, in particular in marine waters. Such complexities do not arise in agriculture where land property rights are clearly defined with respect to private ownership and governmental jurisdiction.

The potential for aquaculture development in Canada is generally accepted as considerable. Of the over 30 cold-water species suitable for aquaculture in our temperate climate, less than a third have been commercially cultured. The real potential of aquaculture to contribute to economic productivity and employment in the nation generally, and especially in the rural areas where such developments are most probable, is impossible to assess with any quantitative credibility. There are a number of reasons for this:

1) Technology, and consequently our understanding of the resource potential, is advancing rapidly. Any attempt at future projection is soon out of date.
2) Adequate assessment of the financial viability of most operations is not available and hence their potential for future growth or even survival is impossible to predict.
3) There is at present no clear government policy on the perceived social and economic value of aquaculture, and hence the likely priority and support it will receive are uncertain. This is in marked contrast to the parallel food producing systems of the traditional fisheries and agriculture.

The potential contribution of aquaculture to the world protein supply generally, and especially that of developed industrial nations, is often misunderstood and/or misrepresented. Clarification is essential to a realistic approach to development planning for aquaculture in the Canadian context, both as a source of food and as an economic development opportunity.

The potential of aquaculture developments to job creation in Canada, especially the less developed areas of the country, is substantial. Aquaculture can provide employment opportunities which complement the skill and training requirements for other resource-based industries in rural areas, such as farming and fishing. Employment created by aquaculture development is compatible with these traditional lifestyles and is therefore an effective means of providing employment in rural areas without disruption to its social fabric.

On a world basis, aquaculture currently accounts for 10% of fisheries production. Fisheries as a whole contributes 5% of the total protein produced, aquaculture being responsible for less than 1%. Only in a relatively few, predominantly underdeveloped nations, does aquaculture make a significant contribution to basic human nutrition, though in many of these it is extremely important and has a potential for dramatically changing the quality of life there. A very real potential exists for expansion and improvement of the already significant role that Canada plays in providing both technical and financial support to such development. On a global basis, however, even if the projected dramatic increases in growth in aquaculture production become a reality, aquaculture is unlikely to affect the level of production of staple foods in most developed nations.

As in the present case, the future target of aquaculture in Canada will be the high unit value, luxury food items which are capable of generating the returns required to meet the necessarily high costs of production imposed by our economic, social, geographic, and climatic conditions. The true potential of aquaculture in contributing to G.N.P., employment and social stability will depend on our ability to develop innovative technologies for fisheries production which are economically viable in the long term and to encourage the participation of aggressive and imaginative entrepreneurs to develop this industry. Their initiatives must be carried out in the context of Canada's unique social, political, economic, and financial climate. Moreover, they must be capable of responding to the needs of this new industry and, at the same time, be able to reconcile their requirements to other reasonable, though conflicting, human desires. A realistic basis for the early appraisal and projection of the economic viability of aquaculture is an obvious and essential first step in the planning process; it is one which has been inadequately addressed in the past.

INTERACTIONS IN AQUACULTURE DEVELOPMENT

The very nature of aquaculture results in many and complex interactions with other human activities and interests. These extend to all phases and aspects from acquisition of materials and seedstock, through the production site to the market place. For purposes of orderly presentation, the major components of these interactions can be grouped under a number of headings:

Physical

This essentially involves competition for water use, its precise nature varying with the location and type of aquaculture operation. In land-based flow-through operations using surface or ground water, there is competition for water volume with domestic or other industry users or conflict with the water requirements of traditional sport or commercial fisheries. Where the production units are located on or in the surface of natural water bodies, lakes, rivers, oceans, competition is more usually concerned with use or access to the areas involved. The competing activities include commercial and sport fisheries, navigation and a variety of recreational activities. In the Bay of Fundy, for example, the location of salmon sea cages in the vicinity of the herring weirs has been alleged to interfere with this traditional fishery. Human leisure activities present particularly serious and growing pressures, sharing as they do with aquaculture many features which make a site desirable: shelter from weather and wave action, warm, uncontaminated water, and relatively undeveloped, often isolated areas.

Environmental

Maintenance of satisfactory water quality is of primary importance to aquaculture, which is probably the human aquatic activity most sensitive to environmental degradation. The effects of waste products from other activities — domestic, industrial, or agriculture — may, however, be positive or negative or even a combination of both. Chemical contaminants may cause direct mortalities or make the product unfit for human consumption. Organic pollutants such as sewage may cause an increase in productivity of benefit to the culture of grazers such as molluscs, but augment the fouling problems of caged fish culture. Discharge of such animal wastes may also result in sanitary conditions, preventing direct marketing of filter feeders such as oysters, mussels, and clams. Aquacultural operations themselves generate such organic wastes which may have undesirable effects on the water quality requirements of other users, downstream or adjacent to the source of them, including other aquacultural operations. Alternately, such interactions between the culture of different species has a potential for mutual advantage, culminating in polyculture in the more sophisticated enterprises.

One industrial waste product which can be of major benefit to aquaculture in areas of climatically limited seasonal growth, such as on the Atlantic coast, is thermal effluent from coal or oil-fired electric power generating facilities. Already successfully utilized to some extent in salmonid culture, it offers considerable potential for expansion in scope and scale.

Biological

Aquaculture, using native species, usually also the target of valuable sport or commercial fisheries, can act as a source of disease organisms and therefore threaten natural stock occupying the same water body. The movement of stocks betweeen watersheds or other separate water bodies, a common feature of aquaculture, adds to the potential for disease dissemination.

Where native species are used there is also a danger of undesirable effects on the genetic makeup of local stocks as an accidental byproduct of increase in efficiency and sophistication of aquaculture techniques. The genetic traits most desirable for aquaculture stock are often quite different from those appropriate to wild populations. The use of transplanted stocks and, increasingly, the development by selection of specialized strains for aquaculture may, viaaccidental escapes, result in dilution of the unique gene poolof a native stock tuned to a specific environment by a long, natural process.

If exotic species are used in aquaculture, there is a very considerable and well documented potential for undesirable ecological effects from the target species itself, orfrom other associated organisms. Such effects include competition with native species and the introduction of undesirable commensals, parasites, or predators. Even initial experimental trials demand elaborate and expensive control mechanisms to prevent such potentially long-term and often catastrophic or expensive results. This problem has significant international implications for Canada. On the Atlantic coast, massive introductions of Pacific salmon, in particular cohosalmon by certain New England states, have resulted in coho being observed in salmon rivers in New Brunswick and Nova Scotia.

Social

Some of the negative social interactions attributed to aquaculture result from the relatively recent development of much of the present aquaculture activity; these reactions can be expected to diminish or disappear with greater general familiarity or acceptance of aquaculture within thecommunity. There are, however, more substantial interactions which demand resolution.

The matter of space competition has been noted earlier. Another parallel concern of leisure users and upland owners or residents is the effect on aesthetic values, particularly where commercial aquaculture uses structures on the water surface. Such conflicts have seriously circumscribed or prevented development in some areas.

The general perception of many of the species used in aquaculture as a traditional common property resource results in another aspect of social pressures. The presence of highly desirable fish species under confinement presents a threat to site security additional to that posed by conventional criminal activities.

Aquaculture techniques such as salmon sea ranching inevitably involve harvest competition with the traditional fishery. Similar competition between the seedstock needs of conventional fisheries and those of aquaculture and even among aquaculturists themselves may be a feature of stocks with naturally limited or managed seed stock resources, e.g. oysters and salmon.

On a global, long-term basis, the present widespread western practice of culturing "luxury" species high on the food chain and incorporating in their feed high quality animal protein, in itself directly useful as human food, may require examination in a world human society where such protein is critcally under-available to many populations.

Economics

Modern transport makes the market for almost all the probable products of Canadian aquaculture essentially global in nature. This is particularly true of processed products with a relatively long shelf life. Accordingly, market competition from domestic or offshore sources producing similar or replacement species must be a serious consideration. The penetration of Norwegian salmon on the North American market is a case in point. In the development of domestic policies, the potential inequity of the effect of direct or relatively hidden subsidies on competing products from fisheries or agriculture may restrict aquacultural market opportunities. An opportunity for the aquaculture point of view to be expressed in the development of economic policies is clearly required. It is important to note that the quality of the aquaculture products is generally superior to the same species "caught-in-the-wild" and accordingly commands higher prices in the marketplace. Consumer preferences will play an important role in the development of the aquaculture industry.

RESOLUTION OF CONFLICTS

The complexity and potentially undesirable effects of the interactions outlined above demand an attempt at their resolution or at least minimization. Important priorities are the use of the water resource generally and the coastal zone especially. Other issues to be addressed include the control of stock movements, pollutants, the importation and/or use of exotics, and disease control.

The appropriate mechanism for resolution of many conflicts is through government policy mediated by regulation. The comparatively short history of much of Canadian aquaculture and its present rapid rate of change have resulted in a generally unsatisfactory regulatory structure, apparatus and function. In general, existing statutes are applied, originally framed for different purposes or minimally adapted to present realities and needs. This is, with some outstanding exceptions, particularly true of fisheries regulation, perhaps the most relevant and basic area of jurisdiction.

The multiplicity and complexity of interactions with aquaculture result in the involvement of many agencies. Table 1 depicts the range of involvement by federal and provincial governments in aquaculture. The listing is not complete but is demonstrative of the interactions and the need for an effective mechanism to facilitate interagency cooperation.

Elements of the coordination between many of these agencies is improving; nevertheless, the development of an effective formal structure for interaction and mutual exchange and communications is very desirable. The intending or practising aquaculturist faces an array of regulatory agencies which is often bewildering and even elusive, which needs clarification, simplification, and synthesis with the aim, so far as this is realizable, of reduction to a minimum of direct interagency contacts. The ideal, doubtfully achievable, would be a single, central clearing house. Other approaches are presented later.

Table 1. Governmental activities in aquaculture.

Federal	
Department of Fisheries and Oceans	— management of fisheries resources
Department of Agriculture	— registration of feeds and vaccines
Department of Health and Welfare	— registration of drugs; feed additives
National Research Council	— funding of R&D projects (e.g. P.I.L.P.)
Department of Trade and Commerce	— funding support and business development
Department of Indian and Northern Affairs	— sponsors projects by native peoples
Department of Supply and Services	— provides incentives for R&D funding
Department of Energy, Mines and Resources	— supports research on energy conservation
Department of Environment	— pollution control and shellfish sanitation
Canada Employment and Immigration Commission	— job creation and training incentives
Department of Transport	— impacts on navigation
Department of Regional Industrial Expansion	— provides funding in fisheries sector
Provincial[a]	
Department of Fisheries	— administration of fisheries loan boards, promotion of fishing industry
Department of Natural Resources	— management of freshwater fisheries
Department of Commerce and Development	— incentives for commercial and industrial development
Department of Environment	— pollution control, environmental impacts, ground and surface water supply
Department of Municipal Affairs	— regional and municipal land use planning
Power Commission/Energy Board	— support projects on energy conservation

[a] Department nomenclature varies with each province; titles are representative.

Regulation should be a mechanism to clarify the opportunities available and facilitate development, not as currently conceived by the industry, as a necessary evil to be combatted and where possible circumvented or removed. It can only be effective if it is, and is clearly seen to be, under constant and critical review in a context of clear aims and principles. A primary aim should be that of public service rather than administrative convenience, and wide-ranging effective industry advisory input an essential prerequisite.

A REVIEW OF THE CONSTRAINTS ON AQUACULTURE DEVELOPMENT

The basic requirement for the development of aquaculture, or indeed any other commercial enterprise, is that it be capable of yielding an acceptable return on the investment required. Many factors affect this: the efficiency of the operation; employment of competitive technology; market conditions; etc. The most important is the achievement of reliability and predictability of production parameters in the medium or long term, so far as consistent with the vagaries of climate and other intangible factors inevitable in biological production systems. Much of what follows is concerned with minimizing the effect of factors which contribute to the present variability and inconsistency associated with aquaculture developments.

Many of the significant constraints to aquaculture in Canada are derived from the lack of definition of the status of aquaculture and its acceptance, socially and officially, as parallel to other food producing systems and therefore meriting similar treatment. This results in a lack of a basis on which to assign appropriate priorities for establishing support mechanisms and structures and solutions to the more obvious constraints, or strategies to develop these.

The major areas of such constraints are summarized below. The relative importance of these vary regionally and provincially. An attempt has been made to stress factors of general applicability but the list, as a whole, has particular relevance to the Atlantic Provinces. Areas of constraint have been grouped under subheadings for convenience and clarity. In fact, most interact with many others to form a web of interdependence leading to a further subtle but significant constraint. It is very desirable, for optimum progress, to advance on a broad front covering all the present and predictable impediments. Limits on applicable resources will inevitably demand the setting of priorities which will be further modified by emergency situations and other problems of immediate commercial significance. The ideal should not be forgotten, however, and a general watching brief be maintained to allow productive periodic program review.

Site Tenure

It is immediately apparent that the intending producer investing his own funds or seeking investment or loan financing and anticipating an enterprise with some degree of long-term stability must have some assurance of security of tenure of his operating site. This must be comprised of an exclusive, continuing occupancy with a clear right to restrict or even prevent harmful access or encroachment, and a clear legal position on ownership of stocks. At present, the status of these rights is unclear at best and often totally unsatisfactory or nonexistent. A thorough review is essential to clarify their status for the producers and to point the way to mechanisms to remedy deficiencies.

The question of tenure is particularly relevant to the marine coastal zone where even the authority legally empowered to exercise jurisdiction over proprietorial rights to the bottom, water column and surface is not at all clear. The ultimate resolution of this contentious legal matter, parallel in many ways to the present debate on jurisdiction over offshore hydrocarbon and mineral resources, may well require a Supreme Court decision. There is, however, a potential for an interim working solution by intergovernmental agreement, similar to those existing in the Maritime Provinces for leasing underwater lands for shellfish culture. Such agreements could be extended to include other species and the use of the surface and water column.

Site security must also incorporate prevention of undesirable interactions between aquaculture operations. No matter what species is grown or technology employed, any water body has a finite carying capacity, whether it is to provide food or oxygen or to absorb waste products. To avoid mutually disadvantageous effects on neighboring operations, limits will be necessary on size, number, and separation of ventures using the same water mass. As the key parameters are site and species specific, a flexible control mechanism will be necessary, based on an adequate knowledge of local conditions and their seasonal variation.

Site Selection

A site possessing the basic conditions allowing the proposed activity is an obvious initial requirement for an aquaculture operation. In the early exploratory stages of development, merely acceptable site characteristics might suffice; later, in a developed competitive industry, a site as close as possible to optimum is obviously advantageous. Many factors must be considered in the choice of a site, such as access, availability of labor, proximity to transportation, and markets. Those factors directly affecting crop production are usually given priority and are perhaps of primary concern. Any decision in this area should be based on a reasonably long time series and from a wide-ranging survey. It is unlikely that an individual entrepreneur is capable of such an activity and such surveys are appropriate activities for government agencies.

The relevant criteria vary with species, even specific stocks, technology available and, most importantly, with time. Such dynamic factors are application of technical developments, introduction of new species, and even changes in eating habits and market demand. For example, though the potential for large-scale mussel culture in the Maritimes was recognized at least 20 years ago, only the comparatively recent market demand has made their commercial production a rational enterprise. Other examples would include the introduction of the European flat oyster, the development of seed collection and suspended growing techniques for the sea scallop and discovery of areas allowing overwintering of Atlantic salmon in sea cages, as well as other salmonids. These developments have provided a considerable potential for aquaculture development on the Atlantic coast of Nova Scotia, Bay of Fundy, and areas in Prince Edward Island and Newfoundland which formerly showed little or no promise.

This dynamic aspect of appropriate criteria for site suitability makes the often proposed designation of areas for aquaculture, difficult to conceive as more than of short-term validity, unless it can in some way allow for future changes.

Water Quality

Water quality is a critical criterion for site selection but, perhaps most important to the aquaculturist, is a high degree of its long-term stability. The considerable investment of time and capital in the crop common in aquaculture, demands some assurance of harvest.

Water as a medium passing through all aquaculture enterprises makes them especially vulnerable to deleterious effluents from near or even moderately distant other human activities. Shellfish growing enterprises have been closed down by deterioration in the sanitary quality of the growing waters; municipal and industrial wastes and other toxic chemicals pose a threat to both survival and edibility of the product, usually with little or no chance of compensation for loss of stock, investment, and opportunity. There is an urgent need for capable legislation to prevent or minimize such effects where possible or to provide for realistic compensation.

Regulation

The multiplicity and complexity of regulatory authorities have already been noted and can constitute a considerable constraint, especially on small-scale enterprises. Also, in some cases, existing regulations themselves are designed for a hunting fishery on natural stocks. For example, minimum legal size limits are inappropriate when applied to culture operations. In fact, some regulations, if applied, would even prohibit aquaculture operations. On the other hand, desirable regulation is often lacking. As suggested earlier, a detailed review and revision of regulations pertaining to aquaculture are long overdue.

Economic

The financial and social return on investment is, as noted above, the acid test of the potential for aquaculture development. All too often technical feasibility is mistakenly equated with financial viability rather than, as it is, the first step towards it. It is suggested that availability of funding would follow demonstration of a probability of return on investment comparable to other opportunities whether the investment source be the private sector or government development funds. This requires the detailed financial analysis and realistic projection of the results of pilot or fully commercial operations. Government support of pilot operations designed to develop appropriate data may well be required in the pioneering phase of development.

The market potential will be an integral part of this analysis. There will also be a continuing demand for market intelligence, including consideration of offshore competition and projections of the short and medium term supply/demand situation. This is particularly relevant to aquaculture where the time required for crop production is measured in years rather than months and the investment in the crop at harvest is high.

Technical Development

The continuing improvement of technology and development of innovative rearing strategies and equipment is essential to the maintenance of a viable, competitive industry. There is a wide range of relevant areas of application, e.g. nutrition, disease control, selective breeding, inventory control, equipment design, processing, transport, etc. Priorities should be based on sensitivity analysis of the components of the cost accounting process referred to above, and those factors likely to have the greatest economic impact given preference. Such development work should be a blend of government, in-house, R&D and contract work with the private sector and within the producing industry itself, with government financial input, if appropriate. Industry cooperation and continuing input will be essential to maximize productivity.

Species

It is important, early in the process of aquaculture development, to carry out a detailed and comprehensive survey of potential candidate species, including exotics. This avoids the naive acceptance of restriction of opportunity to native species and familiar technology and, as much as possible, expensive later changes with the associated high cost and wasted development funds and time. Commercial feasibility and profitability are the ultimate criteria for selection.

Many examples of the value of exotics could be cited from the highly successful aquaculture developments in other countries. The very real and potentially catastrophic hazards of introductions should not, however, be dismissed. Canada has taken a lead role in developing and demonstrating responsible and workable protocols for considering and carrying out introductions, including the establishment of quarantine facilities and related assessment measures. Such procedures should continue to be rigidly applied, under close governmental supervision, for the protection of both native and culture fisheries.

Stocks

Having decided on the species to be reared, reliance on wild stocks not necessarily best suited to culture is a major constraint in early development. Survey and selection from the array of natural, genetically distinct stocks already in existence are important first steps. This should be followed by selective breeding for specified, commercially advantageous traits for species where the broodstock and juvenile production are part of the rearing process. Early gains in selective breeding are often quite dramatic and a stock development program should be an early and high priority. In this, field testing of candidate stocks under commercial conditions is essential and industry involvement in such programs is mandatory, though the technical requirements of the selective breeding itself is likely to be beyond their technical or financial capability.

Climate

Our climatic conditions exert serious constraints on the efficiency of labor utilization and return on capital investment because of the restricted growth season. There are, however, some compensating advantages gained in the culture of species, e.g. salmonids and molluscs, which have a relatively low upper temperature tolerance and the general market acceptance of superior quality in northern products. Energy-efficient technologies which will extend the growing period, such as the use of thermal effluent, water recirculation systems, and solar or other low cost native energy sources offer considerable potential for profitable application. There are, however, potentially undesirable side effects, such as increased activity of disease organisms or physiological phenomena, e.g. maturation and meat quality, which must be included in any appraisal of the applicability of such technology.

PLANNING FOR AQUACULTURE

It has been recognized by many that the most significant problem facing aquaculturists is the indefiniteness of regulation. What may be permitted now may subsequently be prohibited or altered, causing uncertainty in the business plans, along with unpredictable increases in operation costs. These problems are serious enough in well established industrial sectors; they can be devastating when applied to a developing aquaculture enterprise. In Canada there is a clear need to establish a process whereby those agencies with authority over aquaculture can bring their concerns to a common point of discussion so that a consistency of direction can be given to the private sector with respect to aquaculture developments. Because of responsibilities for freshwater fisheries generally being delegated to the provinces, there is less confusion in this field. The responsibility for mariculture is clearly another question.

Before one can consider the planning process for mariculture in Canada, one must address the complexities of management within the "coastal zone" itself. With the passage of the Coastal Zone Managment Act (1972) in the United States, clear recognition was given to the importance of this zone and the need to optimize its uses. The first initiative was to define the zone, its seaward and landward boundaries, and then to develop specific plans for protection, recreation, fisheries and wildlife, port and harbor development, urban and industrial expansion. On the east coast of Canada, several initiatives were undertaken in the early 1970s to promote and implement the concept of coastal zone management in various areas of the Maritime Provinces. The complexity of the issues, jurisdictions and means of implementation soon undermined these initiatives for comprehensive coastal zone management. Perhaps one positive result of these efforts may be reflected in the resource mapping that has taken place since that time (e.g. Chedabucto Bay and Nova Scotia, Bay of Fundy and Passamaquoddy Bay, New Brunswick). However, resource maps, despite their usefulness, are not a substitute for planning. Moreover, in the development of proposals for coastal zone planning there was no specific identification of areas of particular importance for aquaculture. Aquaculture was assumed to fall within the general category of fisheries resources.

Since the publication of these reports and proposals on Maritimes coastal zone management, a number of new regional developments have taken place in aquaculture, most notably with mussels and salmonids, and increased attention is being focused on these developing industries. We have also been able to take into account the promulgation of the USA National Aquaculture Act (1980) whereby the commercial potential of aquaculture and the need for establishing and implementing aquaculture development plans were identified and the respective roles of government and the private sector were defined. This legislation is not particularly germane to the Canadian situation, it illustrates, however, the requirement for aquaculture to have a legislative framework in which to operate and develop. More recently, an Aquaculture Act is before the Nova Scotia legislature which would go far in this direction. When promulgated, it will still require considerable multiagency cooperation to be effective. It represents, nevertheless, an important step in recognizing the needs of this developing industry.

With the prospects for mariculture in eastern Canada improving, and the economic projection of certain aquacultural sectors being positive, there is a requirement to establish an institutional framework which will facilitate and stimulate the orderly and effective evolution of aquaculture to an economically viable and productive industry. To date, aquaculture development has lacked strong government commitment. Although the Department of Fisheries and Oceans has been one of the leading government agencies supporting the development of aquaculture in Atlantic Canada, its mandate in aquaculture is limited without provincial cooperation. In 1978, an Aquaculture Coordination Office was established in Halifax to assist aquaculturists in the Maritime Provinces with the provision of technical advice, points of contact in other agencies, names of scientific experts in such fields as fish health and nutrition, and to provide related information. Aquaculture Permits, renewable annually and issued under the Canada Fisheries Act, were provided to all salmonid aquaculturists. Substantial progress has indeed been made in support of the development of commercial Atlantic salmon aquaculture in such areas as fish health protection, vaccine development, smolt seedstock production, diet formulations, and R&D funding for environmental site evaluations and pilot scale growout facilities. Communication with aquaculturists and with provincial agencies has been closely maintained on the personal contact basis, by annual workshops (e.g. Atlantic Fish Health Workshop) and ad hoc groups (e.g. New Brunswick Seedstock Committee). Unfortunately these mechanisms, although relatively successful in addressing certain problems related in general to a single species, are not sufficiently comprehensive for the development of the aquaculture industry as a whole.

There is now a need for federal and provincial governments, particularly those with marine coastlines, to support and develop the policy framework that is required for the development of an economically viable aquaculture industry. The socioeconomic advantages resulting from an integrated approach have been clearly demonstrated by the success of aquaculture in Japan and Norway. The various important components that make up the aquaculture industry, such as (a) acquisition of land–water rights including exemption from navigational waters legislation, (b) acquisition of seed stock including factors such as fish health and use of exotic species, (c) feed sources and additives, (d) disease control and use of antibiotics, (e) processing and products inspection, (f) product development and marketing, (g) research and development, (h) investment and insurance, should be assessed by government agencies in the context of indentifying their respective roles and responsibilities for aquaculture development. The clarification of these functions on an intergovernmental basis should ultimately lead to the preparation of guidelines and, as required, regulations which would give clear direction to the industry with respect to its property rights, the use, disposal and transfer of fish, and to its commercial activities.

It is clear that most of the planning for aquaculture development in Canada should proceed on a province-by-province basis.

The complexity of jurisdictional issues and legislative responsibilities, as well as the multidisciplinary nature of the scientific and technical issues associated with aquaculture, should not obscure the objective of making a more receptive environment for aquaculture development in Canada. The benefits to be derived from the planned development of aquaculture are many and include:

1) increased fish production, improved quality and variety of fish products, for domestic consumption and export,
2) the creation of jobs and meaningful employment opportunities in a manner reflecting the traditional way of life and compatible with the social fabric of the fishing community,
3) a means of encouraging the "holistic" use of the fisheries resource base and of introducing a longer range stability in the fisheries sector,
4) maintaining a continuity of product supply by developing culture technology for fish stocks no longer self sustaining,
5) applying the scientific approaches used in aquaculture (e.g. disease control, selective breeding, nutrition) for the improved management of natural fish resources.

Fish production from all fisheries sectors, including aquaculture, should be more closely integrated to ensure a stable supply of fish products for domestic and export markets. To this end, we must move towards adopting an integrated policy for fisheries resource management. The development of aquaculture should proceed in a manner acceptable to the respective mandates of both federal and provincial jurisdictions, and at a rate which is compatible with technological capability, environmental standards, and the social objectives of the community.

This planning would be most effectively achieved by the establishment of federal/provincial Aquaculture Resources Planning Boards, eventually one for each province. There could be federal and provincial co-chairpersons, with equal formal representation from both levels of government with participation by the industry. These Boards would be tasked with the identification of the planning elements necessary for the development of the aquaculture industry in each province. The primary task for Aquaculture Resource Planning Boards would be to develop a comprehensive aquaculture development plan for the province, taking the following aspects into account:

Aquatic resource survey.

— assess resource survey inventories and maps to determine geographic areas with the most potential for aquaculture development,
— determine environmentally sensitive areas where industrial/urban development could severely jeopardize future aquaculture development,
— determine where opportunities for aquaculture development exist in association with other fisheries activities or other indusrial sectors, e.g. thermal effluents,
— consider environmental impacts of aquaculture operations and areas of interaction with existing fisheries.

Candidate species for aquaculture:

— review the relevant species which can tolerate cold water and temperate climates, and prepare information base on species of promise,
— review projects carried out to date with candidate species and reassess their potential,
— develop candidate list of species for future feasibility assessments.

Technology development:

— review status of technological applications and assign priority to those proving effective and viable,
— assess applications for R&D funding for new technology development and related pilot scale life support systems,
— identify requirements for technological development in such areas as:
    (i) facility planning and design,
    (ii) environmental site applications,
    (iii) disease control, nutrition, selective breeding, reproduction control, growth enhancement,
    (iv) water supply, recycle and treatment, energy conservation,
    (v) monitors, sensors and automated controls, data processing,
    (vi) feed manufacture and distribution,
    (vii) fish and shellfish culture methodology.
— assess the effectiveness of the mechanisms for technology transfer.

Markets and product development:

— review status of existing aquaculture products in domestic and export markets and determine if there is room for improvement in production, quality, timing, and marketing strategies,
— determine what opportunities exist for new products and how these might be used to stabilize or enhance aquaculture production,
— determine if there is advantage in promoting the creation of cooperative marketing groups,
— develop a system to collate statistics on production and marketing in the aquaculture industry.

Finance, loans, and insurance:

— consider the approaches currently available in support of commercial aquaculture and develop ways to regularize the provision of information to aquaculturists,
— develop a process where requests for financial assistance, low interest loans, and grants are compatible with the planned objectives for aquaculture development in the province (all applications should be critically reviewed for technical merit and feasibility, and their relevance to governmental objectives),
— the basis for premiums related to aquaculture insurance should be periodically reviewed,
— consider methods of processing claims to government with respect to compensation (i.e. destruction of diseased stocks).

Legal framework:

- review the role and responsibilities of all agencies, federal and provincial, with an influence on aquaculture development in the province and determine the need for guidelines and regulations,
- consider formulation of legislation related to tenure and property rights for aquaculturists,
- consider development of regulations under the Fisheries Act for:
  - (i) introduction of exotic species,
  - (ii) commercial salmon sea ranching,
  - (iii) the preservation of genetic diversity in natural stocks.

Communication:

- develop effective information and extension services for aquaculturists,
- encourage formation of aquaculture producer associations and consider methods for public and private sector involvement in aquaculture development.

SUMMARY AND RECOMMENDATIONS

The foregoing has attempted to identify the many interactions, conflicts and constraints that are currently influencing aquaculture development in Canada. The large number of agencies with an involvement in aquaculture, yet the lack of policy recognition for the industry, clearly demonstrates the need for governmental initiative to develop the economic potential of this activity. There is a requirement for a greater recognition and integration of aquaculture within the national fisheries policy as well as mechanisms for provincial and federal authorities to cooperate in their support of aquaculture developments on a province-by-province basis.

The following recommendations are offered for consideration:

1) The federal lead role in aquaculture should continue, in those areas where fisheries management is a federal responsibility, in recognition of existing general jurisdiction and capability.
2) A definition of the status and priority of aquaculture in the general context of national and provincial fisheries policies must be determined.
3) The resolution of jurisdiction over proprietorial rights (especially in inshore marine environments), the development of a comprehensive leasing system, and a review and rationalization of fisheries and other major regulations which impinge on aquaculture developments should be addressed.
4) A thorough and imaginative review of candidate species including available technology, ecological impact, market projections, and commercial feasibility should be carried out for each region.
5) A review and analysis of the economics of aquaculture production and marketing, including the development of short-term projections, should be conducted as a basis for investment/support decision making.
6) An effective R&D support program should be established on an intergovernmental consultative basis with allocations based on sensitivity analysis of cost components as identified in 5) with funding provided for technology development or pilot project support as appropriate.
7) Federal/Provincial Aquaculture Resources Planning Boards should be established to provide coordination between and advice to major development and regulatory agencies and the aquaculture industry.

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THE HUMAN RESOURCES FOR AQUACULTURE IN CANADA

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ABSTRACT

THOMSON, R. G. 1984. The human resources for aquaculture in Canada, p. 88–103. *In* G. I. Pritchard [ed.] Proceedings of the National Aquaculture Conference — strategies for aquaculture development in Canada. Can. Spec. Publ. Fish. Aquat. Sci. 75.

The specific human resources required for the aquaculture industry are outlined by general functional areas of expertise. Current sources of scientific and technical capabilities are listed. Two areas of activity required for the industry are emphasized. The most important is an organized, cooperative public education program to encourage awareness and involvement of more "farmers" in aquaculture. The second is to raise the image of aquaculture potential in educational institutions, both technical and university, to provide more specific programs for direct input into the aquaculture industry.

Suppose that you have just been commissioned to define and establish the infrastructure for the development of food production for the nation — including all the physical, biological, and human resources required — based on the assumption that all food would now be derived from the waters, not from the soil. Assume that your system would be in place before the people to be fed arrived and that your system would be at full function when they arrived. Where would you start?

A little thought would soon unfold the complexity of what is really involved — a mindboggling network of interactions of specific functions come partially into focus — there are still many which won't come sharply into focus and may not for some time. It is one thing to define the system but quite another to find the human resources to start and maintain the system. The human resources must build the system and keep it functioning. Your mind quickly reviews the total system used for food derived from traditional farming because you will need the same type of system with generally similar parts. Diversity of products is immediately apparent in that you can use plants, fish, shellfish, crustaceans, and a few other types to replace the various domestic animals and land plants that were in use. The expertise required in human resources flows from the knowledge of the major resources and functions required for the land system. Some of the disciplines and areas of expertise which must be developed are:

1) Quality water:
   "Water scientists" instead of "soil scientists"
   Environmentalists
   Toxicologists
   Ecologists

2) Quality seed:
   The most productive species grown in the most productive environment.
   Geneticists
   Physiologists
   Meteorologists

3) Growing area:
   Nutritionists
   Hydrologists
   Environmentalists

4) Quality feed:
   Nutritionists
   Feed Producers
   Feed manufacturers

5) Protection from Predators and Disease:
   Diagnosticians, pathologists, bacteriologists, virologists
   Pharmacologists
   Disease prevention expertise and epidemiologists
   Engineers
   Health inspectors

6) Harvesting and Storage:
   Food scientists
   Engineers

7) Quality Control:
   Inspectors
   Food scientists

8) Marketing and Selling:
   Economists
   Marketing experts
   Sales personnel

9) Regulatory Control Functions:
   Water rights
   Transportation
   Licensing
   Quarantine (health regulations)

10) Farmers:
   Shellfish
   Crustaceans
   Finfish
   Plants

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In general, the human resources relate to the general areas of (1) the science and technology of production and production systems, (2) economics and business, and (3) law and public administration. The important functional requirements are education, research, and marketing. Education must be delivered at all levels from extension and continuing education functions for producers, to technical schools, to undergraduate and graduate university education. Research is required at every step in 1 to 10 listed above. Marketing strategies must be aggressively developed and pursued in a very competitive environment.

A summary of problems and areas requiring research is addressed in a recent publication from the National Academy of Sciences in Washington (3) and each item infers the human resources and energies required by the industry.

Production Systems

- Improved technology for rearing cultured species during the early stages of their life cycles.
- Improved technology for formulating, processing, and delivering food and feed for cultured species.
- Construction of demonstration facilities.

Science and Technology

- Research to determine the nutritional requirements of culturable species throughout their life cycles.
- Research to improve understanding of mass culture in order to increase control over behaviour and reproductive processes so that the necessary stocks of seed or juvenile organisms can be developed.
- Research on the genetic characteristics of culturable species in order to develop strains possessing desired characteristics and to preserve natural and domesticated brood stocks.
- Research to improve knowledge of disease organisms and to develop appropriate disease control techniques.
- Research to determine the effects of water quality and the physical environment on cultured species so that techniques may be developed to maintain an optimal environment.
- Establishment of appropriate procedures for registration of all exotic transfers for aquaculture and for effective quarantine to prevent introduction of disease.

Economics and Business

- Research to determine whether markets exist for species that are being considered for aquaculture. Such efforts should be concurrent with scientific research on those species.
- Federal support for public and private research on marketing aquacultural products.
- Research on the relationship between potential aquacultural products and the land, labor, capital, and operating inputs required to produce the species. This research should also examine the relationship between scale of operation and input requirements.
- Financial programs that are now legally available to terrestrial agriculture be made equally available to those engaged in aquaculture.

Law and Administration

- The lead agency take steps to develop appropriate means to coordinate activities among other federal agencies with aquaculture-related programs.
- The lead agency annually submit a report on aquaculture in the United States to the President and the Congress containing a review of existing problems, progress to date, the allocation of funds, and an outline for action.
- The lead agency develop an integrated program that recognizes the assets and skills of existing aquaculture programs within other federal agencies. Such a program should include a National Aquaculture Plan that specifically considers the resources of other federal agencies and contains a timetable for action.
- The lead agency disseminate information concerning federal and state permits and licenses necessary for aquaculture operations and facilitate their acquisition.
- The lead agency develop and promulgate guidelines for state use in enactment of laws and regulations relevant to aquaculture development.
- The lead agency encourage the U.S. Environmental Protection Agency to review and establish specific effluent guidelines and standards for aquatic animal production.
- The lead agency to: (1) identify species of importance to aquaculture; (2) establish a mechanism permitting entry of such species if the public interest will be best served by such entry; (3) develop and distribute to state authorities model regulations for interstate aquatic species disease certifications, and (4) compose and publish a listing of species whose entry into the United States is controlled by statute, but which are approved for use in aquaculture under specified conditions.
- The lead agency take legal and administrative steps to clarify the rights of both public and private hatcheries to harvest the ocean stocks they have planted.
- The Agriculture Extension Service of the U.S. Department of Agriculture be expanded to include services for aquaculturists.

The above list of requirements is suprisingly similar to those listed in *A Development Plan for Atlantic Salmon Aquaculture in the Maritimes Region* by Anderson and Associates in 1980 (1). Many similar topics are included in the Proceedings of the Bras d'Or Lakes Aquaculture Conference in 1975 (6). Many other sources of information relating to aquaculture are available (4, 5, 7, 8, 9, 10, 11, 12, 14, 15).

What has to be done is quite clear, with variations dependent upon the species to be cultivated.

A very encouraging aspect for the future role of aquaculture development, if one could call it encouraging, is the population explosion and potential doubling of the world population by the year 2050, the progressive consumption of some of the most productive farm land in highly urbanized areas in many countries, and the increased attention to animal rights and humane aspects of animal production system. Aquaculture will be able to compete with agriculture as scientific and technical advances develop to support the industry and as the efficiency and economy of food production by other means declines and food prices increase (Fig. 1).

The main constraints on the industry are political and administrative and not scientific and technical.

A lead agency must nurture and guide the aquaculture industry to avoid confusion, particularly in the area of regulations. In the United States, the Department of Agriculture has apparently been so designated. In Canada, Ontario has a Department of Agriculture and Food and is becoming responsible for fish as food. Traditionally, provincial departments of fisheries have been involved with fish, particularly in terms of the sport fishery and less so regarding commercial food. This question requires definition across Canada, particularly because the decisions will have an influence on government support systems and regulations which in turn will be influential in the aquaculture food industry and will influence the requirements for human resources. It might be assumed that the Department of Fisheries and Oceans would be responsible as the lead agency. This conference and past history would support this assumption. If so, could this be confirmed by the Federal Gouvernment?

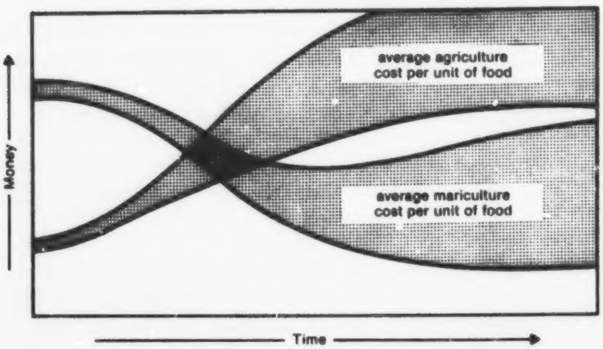

FIG. 1. Postulated dynamics of agriculture and mariculture costs. It is suggested that the costs of food derived from agriculture decreases with expanding populations and increasing industrialization, and as fossil-fuel power becomes more precious. If population levels off, costs of agriculturally derived food will still rise as a result of approaching fossil-fuel exhaustion and the accompanying necessity to convert to other, less economical, energy sources, sources of fertilizers, and means of pest control. It is also suggested that because of the arable space available mariculture costs, by comparison, can decline markedly if capital is directed toward developing the necessary technology — particularly with respect to utilization of conservative energy sources and waste recycling. Mariculture costs might also rise subsequently with general inflation. But they might also continue to decline with technological refinements, The expanding width of the curves, of course, represents increasing uncertainty with time. Note that this graph is conceptual rather than quantitative and that its spatial relationships have been selected to illustrate the concept rather than to predict quantitative relationships (From Hanson 1974).

Where will the human resources come from? How many individuals will be required for each area of expertise? Who will support and provide the educational and training programs?

University programs contribute a variety of disciplinary expertise (Table 1)[2]. There are numerous commercial and nonprofit laboratories and experimental facilities with capabilities in aspects of aquaculture (Table 2). Consultants with expertise in aquaculture function are also available (Table 3). Further support functions are included in Table 4 and Appendices 1 to 4. Some of those listed in the tables are primarily involved with aquaculture whereas others are secondarily supportive of aquaculture.

A search of several calendars from universities and technical colleges revealed several courses specifically directed toward aquaculture (Table 5). It is quite possible that this listing is not up to date.

Certainly the human resources are not concentrated either geographically or by discipline. The variety of expertise and experience is impressive but most is in the scientific disciplines and there is less visible expertise in production systems and marketing. There are individual entrepreneurs with successful operations, particularly in ponds as compared to the sea. Expertise in specific areas such as engineering, nutrition, disease diagnosis and control is of good quality but very thin on a national scale. There is no organized support system, but in general, support comes from individuals who happen by chance to be working in a particular disciplinary related area or geographically related area. Thus specific expertise, as outlined in the beginning of this paper, is generally not available within convenient working distance of many present or potential aquaculture locations. It is probable that this situation will remain more or less as it is until the aquaculture industry secures a higher profile as a significant viable industry in Canada. If the profile expands substantially there should be no difficulty in securing the human resources. But even so, the expertise will tend, for some time, to be adapted to aquaculture rather than directed toward aquaculture. Engineers, nutritionists, pathologists, etc. who received their education and experience in traditional areas are able to shift their expertise to aquaculture. Much more expertise could be shifted if the industry had a higher profile and publicized the opportunities which are and will be available. Poultry nutritionists are now working in fish nutrition and veterinary pathologists are now working on diagnostic problems of disease in aquaculture systems.

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[2] Tables 1 to 4 and Appendices 1 to 4 used with the permission of Dr. G. I. Pritchard (13).

TABLE 1. Analysis of university expertise in Canada in support of aquaculture.

	University (See Appendix 1)																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1. Ethology, systematics, and plankton sorting		X		X						X															
2. Reproduction, physiology, and endocrinology		X								X													X		
3. Feeding, feedstuffs evaluation					X					X															
4. Nutrition, nutrient requirements, and diet formulations					X																	X			
5. Pathology, disease control, and immunology	X		X		X			X				X			X				X				X		
6. Species selection and breeding				X	X					X			X												
7. Ecology, including contamination	X	X		X	X	X	X		X	X		X	X	X		X	X	X		X		X	X	X	X
8. Physiology of growth, juvenile rearing, etc.		X		X	X				X	X	X						X						X		
9. Life support technology and engineering development		X		X	X					X													X		
10. Design and evaluation of production systems					X					X															
11. Legal/institutional/ strategic planning				X																					
12. Food storage and consumer acceptability																					X				
13. Production economics																				X					
14. Marketing																									

Table 2. Analysis of commercial and nonprofit laboratories and experimental facilities with a capability in aquaculture.

	Laboratories and Experimental Facilities (See Appendix 2)																															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
1. Ethology, systematics, and plankton sorting				X								X			X										X						X		X
2. Reproduction, physiology, and endocrinology																																	
3. Feeding, feedstuffs evaluation		X																					X	X									
4. Nutrition, nutrient requirements, and diet formulations																							X	X									
5. Pathology, disease control, and immunology							X		X			X																				X	
6. Species selection and breeding															X	X	X																
7. Ecology, including contamination				X		X				X				X				X	X														
8. Physiology of growth, juvenile rearing, etc.				X										X												X							
9. Life support technology and engineering development	X				X	X						X						X									X	X	X				
10. Design and evaluation of production systems	X	X	X					X			X		X			X	X		X	X	X	X				X		X		X			
11. Legal/institutional/strategic planning																																	
12. Food storage and consumer acceptability											X																		X				
13. Production economics																																	
14. Marketing																																	

Table 3. Analysis of consulting firms with expertise on aquaculture.

	Consulting Firms (See Appendix 3)																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1. Ethology, systematics, and plankton sorting							X								X						
2. Reproduction, physiology, and endocrinology																					
3. Feeding, feedstuffs evaluation																					
4. Nutrition, nutrient requirements, and diet formulations																					
5. Pathology, disease control, and immunology																					
6. Species selection and breeding																					
7. Ecology, including contamination				X							X			X	X		X	X			X
8. Physiology of growth, juvenile rearing, etc.																		X			
9. Life support technology and engineering development					X			X										X	X	X	X
10. Design and evaluation of production systems		X	X		X			X	X	X	X		X						X	X	
11. Legal/institutional/strategic planning	X				X	X					X	X				X				X	
12. Food storage and consumer acceptability																X					
13. Production economics																					
14. Marketing										X						X					

TABLE 4. Analysis of Federal/Provincial research centres with a capability in aquaculture.

	Research Centres (See Appendix 4)																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1. Ethology, systematics, and plankton sorting							X									X			
2. Reproduction, physiology, and endocrinology					X														
3. Feeding, feedstuffs evaluation					X						X								
4. Nutrition, nutrient requirements, and diet formulations	X				X						X								X
5. Pathology, disease control, and immunology			X				X				X		X						
6. Species selection and breeding			X				X			X									X
7. Ecology, including contamination		X	X	X			X	X	X	X		X							
8. Physiology of growth, juvenile rearing, etc.		X	X				X			X					X				
9. Life support technology and engineering development			X				X			X	X	X			X				
10. Design and evaluation of production systems		X	X			X				X			X				X	X	X
11. Legal/institutional/strategic planning		X									X			X					
12. Food storage and consumer acceptability											X								
13. Production economics														X					
14. Marketing														X					

TABLE 5. University and technical college courses directly related to aquaculture.

UNIVERSITY

British Columbia	
Biol. 485	Aquacultural Engineering
Biol. 540	Design of Aquaculture Systems
Guelph	
Nut 71-334	Nutrition of Aquatic Species
Path 73-420	Diseases of Aquatic Animals
Waterloo	
Bio. 452	Introduction to Fisheries Biology — production, harvest, management
Sherbrooke	
Biol. 3662	Pathologie des Poissons
Laval	
Biol. 63296	Aquaculture
New Brunswick	
Grad Biol 6930	Aquaculture
Grad Biol 6932	Developments in Aquaculture
College of Cape Breton	
Biol. 480	Principles of Aquaculture
Dalhousie	
Grad Biol 5600A	Aquaculture
Technical University of Nova Scotia	
540	Fish Processing
541	Fisheries Engineering
St. Mary's	
Biol 207.0	The Atlantic Fisheries

Table 5 *(Continued).*

TECHNICAL

New Brunswick Community College, St. Andrews, New Brunswick (one year)

A—Operation and Maintenance of Physical Facilities:
1—Fabrication and Mending of Dip and Seine Nets
2—Minor Repairs to Small Engines
3—Operation and Servicing of Pumps
4—Materials Fabrication
5—Plumbing using Various Methods

B—Fish Structure and Function:
1—Classification and Structure of Fishes
2—Physiology of Fish
3—Stress — Cause and Effect

C—Fish Health and Epidemiology:
1—General Fish Health and Epidemiology
2—Monitoring Fish Health
3—Control of Infectious Fish Diseases

D—Fish Nutrition and Feeding:
1—Nutrition — Definition and Terms
2—Development of Fish Diets
3—Nutrient Requirements of Fish
4—Feedstuffs as Nutrient Sources
5—Diet Formulation
6—Nutrient Deficiencies and Excesses
7—Feedstuff Selection
8—Diet Preparation
9—Determination of Feed Requirements and Feeding of Fish

E—Basic Hatchery Techniques:
1—Analysis of Water
2—Aeration of Hatchery Water
3—Measuring Water Flows
4—Surface Disinfection of Eggs
5—Measuring of Eggs and Fish
6—Anaesthetizing of Fish

E—(continued)
7—Transportation of Fish
8—Grading of Fish
9—Heating of Hatchery Water
10—Processing of Salmonids
11—Dowsing for Water Supplies

F—Fish Culture:
1—Basic Fish Culture
2—Brood Stock — Collection, Selection, Handling, and Holding
3—Spawning of Fish
4—Egg Handling and Incubation
5—Rearing and Handling of Sac Fry
6—Rearing Fish Beyond the Fry Stage
7—Location of a Fish Culture Operation

G—Fishery Management Techniques:
1—Aging of Fish
2—Marking and Tagging of Fish
3—Stocking of Fish

H—Data Collection, Calculation and Presentation:
1—Calculation of Mean and Percentage
2—Standard Deviation
3—Preparation and Presentation of Graphical Data

I—Economics of Aquaculture Operations:
1—Economics of Fish Culture
2—Marketing of Aquaculture Products

J—Personnel and Office Management:
1—Presentation of Oral Reports
2—Conducting Interviews
3—Staff Relations

Malaspina College, Nanaimo, British Columbia

First Year Courses — First term:
Biology 111 General Biology
English (General English)
Fish 121 Fish Husbandry I
Fish 131 Fish Culture I
Fish 151 Small Motor Maintenance
Fish 171 Field Applications
Fish 191 Project in Fisheries
Mathematics 181 Biometry for Fish Culture

Second Term:
Biology112 General Biology
English 101 General English
Fish 122 Fish Husbandry II
Fish 132 Biology of Fishes
Fish 152 Hydraulics
Fish 172 Field Applications
Fish 192 Project in Fisheries

Second Year Courses — First Term:
Accounting 100 Elements of Accounting
Fish 215 Hydrology
Fish 222 Fish Health
Fish 231 Fish Culture II
Fish 271 Field Applications
Fish 291 Project in Fisheries
Zoology 205 Invertebrate Zoology

Second Term:
Computing Science 170 Computer Applications
English 282 Public Speaking
First Aid Standard St. John's
Fish 211 Mariculture I
Fish 232 Mariculture II
Fish 251 Resource Ecology
Fish 262 Topographic Surveying
Fish 272 Field Applications
Fish 292 Project in Fisheries

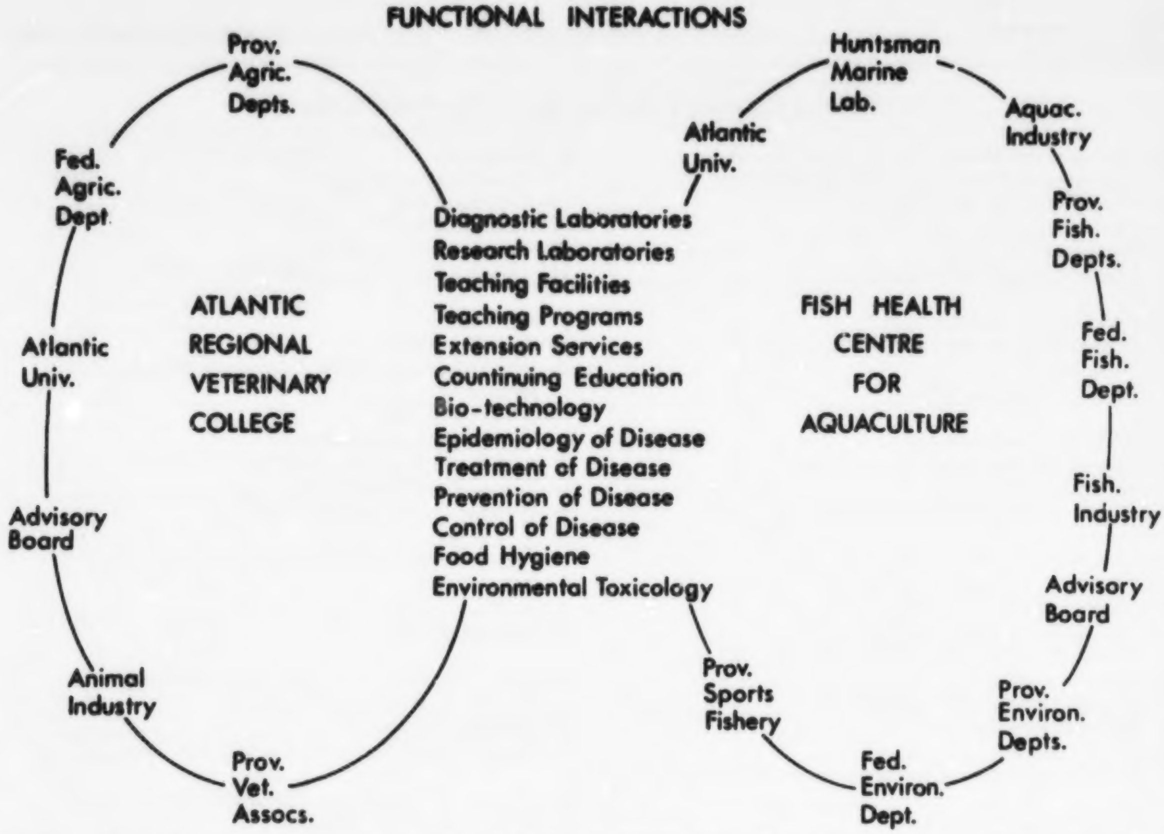
FUNCTIONAL INTERACTIONS
Prov. Agric. Depts.
Fed. Agric. Dept.
Atlantic Univ.
Advisory Board
Animal Industry
Prov. Vet. Assocs.
ATLANTIC REGIONAL VETERINARY COLLEGE
Diagnostic Laboratories
Research Laboratories
Teaching Facilities
Teaching Programs
Extension Services
Countinuing Education
Bio-technology
Epidemiology of Disease
Treatment of Disease
Prevention of Disease
Control of Disease
Food Hygiene
Environmental Toxicology
Atlantic Univ.
Huntsman Marine Lab.
Aquac. Industry
Prov. Fish. Depts.
Fed. Fish. Dept.
Fish. Industry
Advisory Board
Prov. Environ. Depts.
Fed. Environ. Dept.
Prov. Sports Fishery
FISH HEALTH CENTRE FOR AQUACULTURE

FIG. 2. Proposed functional interactions of the Fish Health Centre in Support of Agriculture at the Atlantic Regional Veterinary College (1). Perhaps a new institution is in a position to break new ground, particularly an institution devoted to providing education, research, diagnosis, continuing education, and extenson services to an entire region of Canada. Most aspects of health relate to feeding, breeding, housing, and management and these are usually closely related to disease problems. To coordinate and integrate these functions into the educational, service, and research functions could be beneficial and economical. A coordinated effort would not only be more effective but would be less confusing for those using or receiving the services in the aquaculture industry. These efforts could complement the services provided by individual governments and other agencies.

Many biology graduates could easily adapt to supportive roles in the industry in their undergraduate and graduate programs. A strong statement of the needs from the "lead agency" will be effective, particularly at a time when some university graduates are not fully employed. Developments such as the Fish Health Centre in Support of Aquaculture at the proposed Atlantic Regional Veterinary College could provide and coordinate some support systems on a regional basis (Fig. 2). Perhaps concepts such as this, or with a different emphasis, will be the trend in the future.

In the development of the concept of the Fish Health Centre numerous people associated with aquaculture were contacted and requested to respond to specific questions regarding the needs for aquaculture development in Eastern Canada. Following the response, drafts were sent to several of the respondents for comment. The final version has general approval of those participating in the development of the concept. Probably the most frequently cited areas requiring development by such a Centre were the general areas of extension, continuing education and short courses.

The Aquaculture Technician Training Program, a combined project of the Huntsman Marine Laboratory, the New Brunswick Community College and Canada Manpower provides a "hands on" practical program for the primary producer. Other programs are offered at Malaspina College at Nanaimo, British Columbia and St. Félicien CEGEP at St. Félicien, Quebec. More of such programs are needed and they must provide "real world" experience.

Each of the Atlantic, and probably all provinces, have commitments to aquaculture educational programs although each varies in the approach and probably in the degree of commitment of participants. *These programs need to be maintained, increased, and highly publicized.* They involve the primary producer and it is there that the commitment must be made with full knowledge of what the support programs, markets, hazards and rewards will be. The potential entrepreneurs in fishing villages and towns who live with the sea, lakes and ponds must be made aware of the opportunities and guided to successful enterprises either individually or cooperating in groups.

The aquaculture "farmers" must be mobilized. This is the greatest need in human resources and these resources are available for mobilization.

Perhaps the greatest facilitative need at present is an educational program directed toward people who have experience with the fishery but are reluctant to move away physically from the traditional fishery. Often the two could be combined, particularly in a family enterprise. The National Film Board movie on Norwegian aquaculture (16) deals with practical, scientific, marketing, and social aspects of involvement in aquaculture. This film is an excellent promotion for fish aquaculture, particularly because it deals with how people enter the industry and how they function in the industry. This movie and others like it should be shown *repeatedly* to audiences in areas where aquaculture is possible. Aquaculture could contribute immensely to social problems and unemployment in many traditional fisheries areas.

Departments of Industry, Social Services, Fisheries and Agriculture should combine at the provincial and regional level to promote the aquaculture industry in a consistent well-organized program. The opportunities are available and await development. Let potential operators see and study successful production operations; show them the final product, the quality control system, the marketing strategies; let them see the competitive products on the store shelf, and see how the consumer responds to these products of the aquaculture industry. *Think of the comparable technical, educational, and promotional services available to and used by agriculture across Canada!*

The parts of the wheel of the aquaculture industry can be identified as mentioned above. In general, all the participants required for the industry are available either directly or with some reorientation — the farmers, technicians, scientists, advisors, etc. The question is, how are these human resources to be focussed, stimulated, and moved into action? If these can be mobilized efficiently, the mission can be successful. These resources must be led and enticed, but not driven; led in such a way that the path is clear, well marked and signposted with all the benefits and hazards clearly identified. The resources, human, physical and financial, will expand as the needs and opportunities arise.

Probably all the human resources required for the aquaculture industry are represented at this conference. Now would be an ideal time to lay out the blueprint. We know what has to be done. We know the human resources required and the parts of the machine which must be built. But can we put it together? Can we breathe more life into it and keep it alive and healthy? This conference can speak to Canada and Canadians about the future of the industry with a clear voice and a clear message. It should speak to the average Canadian citizen, not just to the scientists and technicians.

The potential for aquaculture must be emphasized through the various media resources used and available today, particularly to contact people who live on or near water, who know the rivers, lakes and sea, *who have the natural aptitude for working with the creatures of the ponds, lakes, rivers, and the sea*. A well designed program, coordinated and promoted on a regional basis through a group effort, could be very effective.

When cattle ranching started in the West, the human resources soon appeared to support the industry. The same is true of the poultry, swine, and dairy industries.

The participants at this conference collectively have the means to create public awareness of the potential of the industry through education, and demonstration. It would indeed be unfortunate if we left here without a plan for coordinated action toward mobilizing more human resources into the industry through information, extension services, public education, and all forms of the media, with particular emphasis toward the "farmer" and potential "farmers" of the rivers, lakes, and the sea.

Let us not just talk about it, let's do it. We know what human resources are needed. They must be stimulated and mobilized; we know where they are and we have access to the means for delivering the information. It will take time and effort. Let us develop a 5-year overall plan of public education — carry it out — and measure the results. Such an effort could coordinate or complement the activities of governments and aquaculture associations.

Suppose we really are required to provide much more of our food from the waters of Canada!

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APPENDIX 1

Universities with Research Activities Related to Aquaculture

UNIVERSITY	*TOPIC*
1. University of Alberta, Edmonton, Alberta (Drs. T. Yamamoto, J. S. Nelson, etc.)	Fisheries ecology, bacteriology, virology
2. University of British Columbia, Vancouver, B.C. (Drs. R. F. Scagel, H. F. Stich, D. J. Randall, P. Larkin, R. J. Anderson, J. Zahradnik,etc.)	Algal physiology, fish physiology tumors, population assessments, marine microbiology, ethology, engineering
3. University of Calgary, Calgary, Alberta (Dr. R. D. Macdonald)	Virology
4. Dalhousie University, Halifax, N.S. (Drs. K. H. Mann, A. R. O. Chapman, L. E. Haley, R. W. Doyle, B. Wildsmith, C. J. R. Garrett, M. L. Cross)	Algal ecology, oyster genetics, law, coastal oceanography, economics
5. University of Guelph, Guelph, Ontario (Drs. S. Slinger, J. B. Sprague, K. Ronald, H. R. MacCrimmon, G. W. Friars, B. J. Holub, F. W. H. Beamish, J. R. Geraci, H. Ferguson, R. M. W. Stevenson, R. A. Johnston, R. D. Moccia, etc.)	Nutrition, genetics, pathology, toxicology, limnology, bioenergetics
6. Université Laval, Quebec, Que. (Drs. J. J. Dobson, J. C. Terriault, etc.)	Littoral population dynamics of estuaries
7. McGill University, Montréal, Que. (Dr. W. C. Leggett, etc.)	Multispecies interactions
8. McMaster University, Hamilton, Ont. (Dr. R. Sonstegard)	Pathology
9. University of Manitoba, Winnipeg, Man. (Dr. F. J. Ward, N. E. R. Campbell, T. A. Dick, etc.)	Water impoundment ecology, microbial ecology, fish growth
10. Memorial University of Newfoundland, St. John's, Nfld. (Drs. D. R. Idler, G. L. Fletcher, R. J. Thompson, A. Sutterlin, D. H. Steele, etc.)	Fish reproduction and endocrinology, inshore marine, finfish and scallop culture, etc.
11. Université de Moncton, Moncton, N.B. (Dr. B. P. Vezina)	Juvenile lobsters
12. Université de Montréal (including École de médicine vétérinaire, Saint-Hyacinthe), Montréal, Que. (Drs. R. Lallier, G. Cousineau, M. Elazhary, M. Fontaine, M. J. Fréchette, etc.)	Pathology, microbiology and immunology
13. University of New Brunswick (Saint John Campus), Saint John, N.B. (Drs. M. Thomas, C. Schom)	Brackish water and coastal ecology, genetics
14. University of Ottawa, Ottawa, Ont. (Drs. P. Weinberger, S. U. Quadri, etc.)	Experimental ecosystems

15.	University of Prince Edward Island, Charlottetown, P.E.I. (pending)	Fisheries biology, pathology proposed
16.	Queen's University, Kingston, Ont. (Dr. G. W. Van Loon)	Experimental contaminants
17.	Université de Québec à Rimouski, Rimouski, Que. (Dr. R. El-Sabh)	Physical and biological oceanography, larvae fish, etc.
18.	Royal Roads Military College, Victoria, B.C.	Coastal oceanography
19.	University of Saskatchewan, Saskatoon, Sask. (Dr. G. Wobeser)	Pathology, life support systems
20.	Simon Fraser University, Burnaby, B.C. (Drs. G. H. Geen, P. Copes, etc.)	Toxicology, aquatic ecosystems, fisheries economics
21.	Technical University of Nova Scotia Halifax, N.S. (Drs. E. G. Bligh, R. Ackman, J. H. Merritt, T. Gill, etc.)	Food technology
22.	University of Toronto (including Scarborough College), Toronto, Ont. (Drs. A. H. Weatherly, H. H. Harvey, etc.)	Bioenergetics, sublethal contaminants
23.	University of Victoria, Victoria, B.C. (Drs. A. T. Matheson, J. T. Buckley, T. J. Trust, D. V. Ellis, M. J. Ashwood-Smith, etc.)	Toxicology in marine environment, physiology, immunology, egg and sperm preservation, etc.
24.	University of Winnipeg, Winnipeg, Man. (Dr. G. E. E. Moodie)	Benthos–forage–fish interactions
25.	University of Waterloo, Waterloo, Ont.	Limnology

APPENDIX 2

Commercial and Nonprofit Laboratories and Experimental Facilities with Capability in Aquaculture

FIRM	*TOPIC*
1. Algas Resources Ltd., Calgary, Alta.	Use of heated effluents, systems development
2. Apex Bio-Resources Ltd., Duncan, B.C.	Salmon farming, feed technology
3. Aquafarms Canada Ltd., Feversham, Ont.	Trout farming systems
4. Bamfield Marine Station, Bamfield, B.C.	Inshore marine sciences
5. Research Council, Vancouver, B.C. (C. C. Waldon, etc.)	Systems engineering
6. Canadian Benthic Ltd., Bamfield, B.C.	Mariculture, abalone culture
7. Canadian Veterinary Biologics Ltd., Smith Falls, Ont. (Dr. P. H. Langer)	Biologics
8. Cape Breton Marine Farming Ltd., Baddeck, N.S.	Oyster and trout rearing systems
9. Connaught Laboratories, Willowdale, Ont.	Fish vaccines
10. Envirocon, Vancouver, B.C.	Habitat assessment
11. Fisheries Resource Development Ltd., Halifax, N.S. (Dr. J. F. Maloney)	Food technology and resource use planning
12. Fundy Isles Marine Enterprises, St. Andrews, N.B. (Dr. C. Frantsi)	Fish health, culture systems, plankton identification
13. Genu Products Ltd., Dartmouth, N.S.	Marine plants
14. Groupe interuniversitaire de recherches océanographiques du Québec (GIROQ), Quebec, Que.	Estuarine ecology
15. Huntsman Marine Laboratory St. Andrews, N.B.	Systematics
16. IMA Aquatic Farming, Glenwood, N.S.	Salmonid genetics, culture systems
17. International Atlantic Salmon Foundation, St. Andrews, N.B.	Salmonid culture
18. Limnos Ltd., Toronto, Ont. (John H. Neil)	Heated effluent uses, limnology
19. Institute of Man and Resources, Charlottetown, P.E.I.	Solar aquaculture

20. Marine Colloids Ltd., Halifax, N.S.	Marine plant culture
21. Marine Lobster Farms Ltd., Charlottetown, P.E.I.	Crustacean culture
22. Marine Resource Associates, St. Andrews, N.B.	Sea-pen farming
23. Martin Feeds Ltd., Elmira, Ont.	Feed technology
24. Maritime Feed Co-op, Moncton, N.B.	Feed technology
25. Montreal Aquarium, Montreal, Que.	Ethology
26. Myticulture International Inc., Ottawa, Ont.	Mussel culture
27. Nova Scotia Research Council, Halifax, N.S.	Systems engineering
28. Plansearch Marine Division (formerly MacLaren Marex) Dartmouth, N.S.	Ocean engineering, site assessments, mariculture
29. Research Productivity Council, Fredericton, N.B.	Food technology, systems engineering
30. Redonda Sea Farms Ltd., Vancouver, B.C.	Oyster culture
31. Royal Ontario Museum, Toronto, Ont.	Systematics
32. Syndel Laboratories, Vancouver, B.C.	Fish medicines
33. Vancouver Aquarium, Vancouver, B.C.	Ethology

APPENDIX 3

Consultants with Aquaculture Expertise

FIRM	*TOPIC*
1. Anderson and Associates Consultants, St. Andrews, N.B.	Planning and training
2. Aquafarms Consultants Ltd., Nanaimo, B.C. (Drs. T. D. D. Groves, W. Kennedy, etc.)	Business planning and designs
3. G. C. Armstrong Enterprises, Agincourt, Ont.	Hatchery management
4. Beak Consultants, Vancouver, B.C. (R. E. McLaren, etc.)	Habitat quality, limnology, and biological oceanography
5. E. R. Broughton Associates Ltd., Toronto, Ont.	Facilities and strategic planning
6. B. M. Resource Management Inc. Ottawa, Ont. (Dr. Blair McGugan)	Resource use planning and evaluation
7. E.V.S. Consultants, North Vancouver, B.C.	Plankton identification
8. D.P.A. Consultants Ltd., Fredericton, N.B. (A. Robertson)	Aquacultural engineering
9. J. P. Cuerrier, Vanier, Ont.	Fish culture
10. S. J. Ettman, Glen Margaret, N.S.	Tuna culture, marketing
11. Faunaquatics Canada Ltd., Guelph, Ont. (Dr. H. R. MacCrimmon, etc.)	Fish culture, habitat management
12. Robert Fletcher and Associates Ltd., Ottawa, Ont.	Strategic planning, education
13. D. B. Lister and Associates Ltd., North Vancouver, B.C.	Hatchery biology
14. Lombar North Group, Calgary, Alta.	Environmental assessment
15. P. McCart Consultants, Nanaimo, B.C.	Ethology, environmental assessment
16. Fisheries Development Consultants Canada, Ottawa, Ont.	Project and strategic planning and evaluation
17. Monenco Consultants Ltd., Calgary, Atla. (Dr. P. Neame)	Fisheries biology
18. Montreal Engineering Ltd., Montreal, Que. – Halifax, N.S. (P. Ruggles)	Environmental assessments
19. W. P. Truch, Calgary, Alta.	Hatchery engineering
20. Underwood McLellan Ltd., Vancouver, B.C. – Rexdale, Ont. (D. Sinclair, D. Reid, etc.)	Hatchery engineering, culture systems
21. W. L. Kardrop Associates Ltd., Winnipeg, Man.	Water resource planning and engineering, environmental assessment

APPENDIX 4

Federal/Provincial Research Centres with a Capability in Aquaculture

CENTRE	*TOPIC*
1. Agriculture Canada, Ottawa, Ont.	Feedstuffs, biologics
2. B.C. Ministry of Environment, Marine Resources Branch and Fish and Wildlife Branch (R. A. H. Sparrow, G. Halsey, etc.)	Hatchery operations, oyster biology, etc.
3. Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, B.C.	Infectious diseases, immunology, bioenergetics, and growth, finfish and shellfish culture systems
4. Department of Fisheries and Oceans, Institute of Ocean Sciences, Sidney, B.C.	Physical and chemical oceanography, benthic organisms
5. Department of Fisheries and Oceans, West Vancouver Laboratory, Vancouver, B.C.	Fish reproduction and endocrinology, feedstuffs evaluation, and diet preparation
6. Department of Fisheries and Oceans, Pacific Salmon Enhancement Project, Vancouver, B.C.	Salmonid culture systems
7. Department of Fisheries and Oceans, Freshwater Institute, Winnipeg, Man.	Limnology, disease control, contaminants, culture technologies
8. Department of Fisheries and Oceans CCIW, Burlington, Ont.	Water quality
9. Department of Fisheries and Oceans, Quebec Region, Quebec, Que.	Estuarine ecology
10. Department of Fisheries and Oceans, Biological Station, St. Andrews, N.B.	Salmonid genetics and biology, invertebrate culture
11. Department of Fisheries and Oceans, Halifax, N.S.	Fish health and nutrition economics, food technology
12. Department of Fisheries and Oceans, Bedford Institute of Oceanography, Dartmouth, N.S.	Ocean engineering, coastal oceanography, marine productivity
13. Department of Fisheries and Oceans, Northwest Atlantic Fisheries Centre, St. John's, Nfld.	Scallop culture, salmonid culture
14. N.R.C. Altantic Regional Laboratory, Halifax, N.S.	Marine plants
15. National Museum of Natural Sciences, Ottawa, Ont.	Systematics, larval fishes
16. New Brunswick Fisheries Department, Fredericton, N.B.	Heated effluents, finfish culture
17. Nova Scotia Fisheries Department, Halifax, N.S.	Mussel culture
18. Ontario Ministry of Natural Resources, Research Centre, Maple and Guelph, Ont. (P. Ihssen, Y. Cho, etc.)	Nutrition, genetics, culture systems

FEDERAL, PROVINCIAL, AND MUNICIPAL GOVERNMENT ROLES IN AQUACULTURE

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ABSTRACT

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A hypothetical aquaculture business is broken down into three basic component activities — setting up the operation, continuing it, and marketing the product. Each activity is further subdivided into the various concerns an aquaculturist faces, such as selecting a site and a species and protection from pollution. In relation to each concern, the paper looks at the constitutional powers of the federal and provincial governments and evaluates their relative importance. Where appropriate the role of municipal governments is considered. An attempt is made to suggest how, in cases where federal and provincial governments each have an interest, the competing powers might be reconciled.

An aquaculture operation is an integrated enterprise composed of a series of discrete activities. These activities are subject to a variety of physical and financial constraints. For example, seed must be obtained; organisms must be fed; water quality must be protected; fish health must be maintained; profits must, at some stage, be a realistic expectation. Another significant type of constraint must as well be recognized: that imposed by the legal system. Aquaculture is subject to a host of requirements dealing with licences, leases, permits, approvals, and inspections. This bureaucratic plethora is to a large extent unavoidable because governments, and the public they represent, have legitimate concerns which the private operator must address. We might, for example, be concerned about what effect the culturing of coho salmon within the range of wild Atlantic salmon populations might have.[1] Granted some of the administrative burdens imposed can be lightened, as by concentrating responsibility for the processing of an application for a proposed aquaculture operation in one government department or official, say a Director of Aquaculture.[2] But a central problem with this approach, and with the simplification of legal constraints, is that it requires a clear understanding by each governmental entity of what its role is. I propose in this paper to address this issue in relation to the three basic tiers of government in Canada — the federal, provincial, and municipal levels. I will consider the more problematic functional components of a hypothetical, generalized aquaculture operation in relation to the key interests which each level of government might have and the constitutional division of powers in Canada.[3] I will be bold enough to make some suggestions about how, when all is said and done, some responsibilities of each level of government might be aligned.[4] In this analysis the components of an aquaculture operation will, for the sake of clarity, be grouped into three broad functions: setting up the operation, its day-to-day conduct, and harvesting and marketing the final product.

A. INITIAL CONSIDERATIONS

It is generally useful to contrast Canadian and American positions. Often common problems have reached critical proportions in the United States first and we can gain the benefit of their work in attempting to resolve these problems. Thus, the curious reader may wonder how governmental roles in aquaculture are aligned there. Unfortunately, I must report that the constitutional structure is different in the United States. The jurisdictional problems are different and the federal and state roles may be much more easily reconciled and meshed. The situation may be put this way: the American constitution does not distinguish the fisheries resource from other natural resources; all natural resources within state boundaries (including living flora and fauna) come under state control (federally owned land would be an exception); state boundaries extend into the marine offshore at least three geographical miles seaward from the coastline and in some cases (e.g. Texas and Florida in the Gulf of Mexico) three leagues.[5] Thus they do not have our problems relating to exclusive federal responsibility for fisheries, and exclusive provincial control over property in the provinces, and uncertain provincial offshore boundaries. This is not to say, however, that the exercise of federal powers or the existence of areas of federal jurisdiction may not impact upon aquaculture in the United States. For example, in *Hughes* v. *Oklahoma*[6] the United States Supreme Court struck down a state-enacted provision which stated: "No person may transport or ship minnows for sale outside the state which were seined or procured within the waters of this state." This it did because it discriminated against interstate commerce, an area under federal control. The state could legitimately seek to conserve its resources, the Court reasoned, but in so doing must seek ways to minimize the discriminatory impact on interstate commerce. This statutory provision did not apply to hatchery-bred minnows. As well, a recent National Academy of Sciences Report in the United States indicates that more than 20 federal agencies or offices are involved in activities directly or indirectly related to aquaculture. The Report also indicated that while no "federal laws or regulations apply directly to private farming of fish, shellfish or marine plants," there were "federal aquaculture laws" that fell within two categories: "those that apply to waters located beyond state jurisdiction (e.g., the Fisheries Conservation and Management Act of 1976) and those that authorize the conduct of research and development programs and the establishment of federal hatcheries."[7]

Deserving of special mention in the category of American federal aquaculture laws is the National Aquaculture Act of 1980.[8] This statute is not regulatory in nature: it does not deal with licencing operations or leasing lands or controlling species use or inspecting for diseases and similar matters. These continue to be primarily state responsibilities. What the Act attempts to do is set up a framework for future development. In this connection the statutorily-declared "Findings, Purpose, and Policy" as set out in section 2 is illuminating:

> Section 2(a) Findings — Congress finds the following:
>
> (1) The harvest of certain species of fish and shellfish exceeds levels of optimun sustainable yield, thereby making it more difficult to meet the increasing demand for aquatic food.
>
> (2) To satisfy the domestic market for aquatic food, the United States imports more than 50 per centum of its fish and shellfish but this dependence on imports adversely affects the national balance of payments and contributes to the uncertainty of supplies.
>
> (3) Although aquaculture currently contributes approximately 10 per centum of world seafood production, less than 3 per centum of current United States seafood production results from aquaculture. Domestic aquaculture production, therefore, has the potential for significant growth.
>
> (4) Aquaculture production of aquatic plants can provide sources of food, industrial materials, pharmaceuticals, and energy, and can assist in the control and abatement of pollution.
>
> (5) The rehabilitation and enhancement of fish and shellfish resources are desirable applications of aquacultural technology.
>
> (6) The principal responsibility for the development of aquaculture in the United States must rest with the private sector.
>
> (7) Despite its potential, the development of aquaculture in the United States has been inhibited by many economic, legal, and production factors such as inadequate credit, diffused legal jurisdiction, the lack of management information, and the lack of reliable supplies of seed stock.
>
> (8) Many areas of the United States are suitable for aquaculture, but are subject to land-use or water-use management policies that do not adequately consider the potential for aquaculture and may inhibit the development of aquaculture.
>
> (b) Purpose — It is the purpose of this Act to promote aquaculture in the United States by
>
> (1) declaring a national aquaculture policy;
>
> (2) establishing and implementing a national aquaculture development plan; and
>
> (3) encouraging aquaculture activities and programs in both the public and private sectors of the economy;
>
> that will result in increased aquacultural production, the coordination of domestic aquaculture efforts, the conservation and enhancement of aquatic resources, the creation of new industries and job opportunities, and other national benefits.
>
> (c) Policy — Congress declares that aquaculture has the potential for augmenting existing commercial and recreational fisheries and for producing other renewable resources, thereby assisting the United States in meeting its future food needs and contributing to the solution of world resource problems. It is, therefore, in the national interest, and it is the national policy, to encourage the development of aquaculture in the United States.

Other provisions then go on to require that "within eighteen months after the date of the enactment of this Act [September 26, 1980], the Secretaries [of Agriculture, Commerce and the Interior] shall establish the National Aquaculture Development Plan" with certain statutorily mandated contents (s. 4), that the Secretaries of the above-noted departments engage in certain functions, including prescribing "such regulations as may be necessary to carry out the Plan (s. 3), that there be an "interagency aquaculture coordinating group ... to increase the overall effectiveness and productivity of Federal aquaculture research, transfer, and assistance programs" (s. 6), that the Secretaries may contract out actions that they are responsible for implementing (s. 7), that the Secretaries within twelve months of the enactment of the Act conduct "a study of the capital requirements of the United States aquaculture industry" (s. 8), that the Secretaries within the same 12-month period conduct "a study of the State and Federal regulatory restrictions to aquaculture development in the United States" (s. 9), and that a total of $70,000,000 be authorized for appropriation by the Departments of Agriculture, Commerce and the Interior over the 3 fiscal years 1981 to 1983 (s. 10). This statute, even with its seemingly uncontroversial planning, research, and development objects, was several years, many committee hearings and reports, and a variety of abortive bills in the making.[9] One might therefore speculate as to the complexities and time involved in securing agreement where questions of regulatory control and conflicting or uncertain jurisdictions are involved, as is the case in harmonizing federal and provincial aquaculture roles in Canada.

A second, albeit mundane, preliminary consideration is the provisions of the Constitution Acts (formerly called the British North America Acts) which bear on the distribution of powers between the federal and provincial governments. Regard must be had to these provisions and their interpretation by the courts in order to ascertain the limits of federal and provincial powers in areas relating to aspects of the conduct of aquaculture. Note that the Constitution Acts do not directly refer to or assign to either level of government the subject of aquaculture. The appropriate sections to review are the following:

> 91. It shall be lawful for the Queen, by and with the Advice and Consent of the Senate and House of Commons to make Laws for the Peace, Order, and good Government of Canada, in relation to all Matters not coming with the Classes of Subjects by this Act assigned exclusively to the Legislatures of the Provinces; and for greater Certainty, but not so as to restrict the Generality of the foregoing Terms of this Section, it is hereby declared that (notwithstanding anything in this Act) the exclusive Legislative Authority of the Parliament of Canada extends to all Matters coming within the Classes of Subjects next herein-after enumerated; that is to say, — ....
>
> 1A.The Public Debt and property.
>
> 2. The Regulation of Trade and Commerce ....

3. The raising of Money by any Mode or System of Taxation . . . .
6. The Census and Statistics.
7. Militia, Military and Naval Service, and Defence . . . .
9. Beacons, Buoys, Lighthouses, and Sable Island.
10. Navigation and Shipping . . . .
12. Sea Coast and Inland Fisheries.
13. Ferries beteween a Province and any British or Foreign Country or between Two Provinces . . . .
15. Banking, Incorporation of Banks, and the Issue of Paper Money.
16. Savings Banks.
17. Weights and Measures . . . .
19. Interest . . . .
21. Bankruptcy and Insolvency.
22. Patents of Invention and Discovery . . . .
24. Indians, and Lands reserved for the Indians . . . .
27. The Criminal Law, except the Constitution of Courts of Criminal Jurisdiction, but including the Procedure in Criminal Matters . . . .
29. Such Classes of Subjects as are expressly excepted in the Enumeration of the Classes of Subjects by this Act assigned exclusively to the Legislatures of the Provinces.

And any Matter coming within any of the Classes of Subjects enumerated in this Section shall not be deemed to come within the Class of Matters of a local or private Nature comprised in the Enumeration of the Classes of Subjects by this Act assigned exclusively to the Legislatures of the Provinces.

Exclusive Powers of Provincial Legislatures.

92. In each Province the Legislature may exclusively make Laws in relation to Matters coming within the Classes of Subjects next herein-after enumerated; that is to say, — . . .

2. Direct Taxation within the Province in order to the raising of a Revenue for Provincial Purposes . . . .
5. The Management and Sale of the Public Lands belonging to the Province and of the Timber and Wood thereon . . . .
8. Municipal Institutions in the Province.
9. Shop, Saloon, Tavern, Auctioneer, and other Licences in order to the raising of a Revenue for Provincial, Local, or Municipal Purposes.
10. Local Works and Undertakings other than such as are of the following Classes: —
    (a) Lines of Steam or other Ships, Railways, Canals, Telegraphs, and other Works and Undertakings connecting the Province with any other or others of the Provinces, or extending beyond the Limits of the Province;
    (b) Lines of Steam Ships between the Province and any British or Foreign Country;
    (c) Such Works as, although wholly situate within the Province, are before or after their Execution declared by the Parliament of Canada to be for the general Advantage of Canada or for the Advantage of Two or more of the Provinces.
11. The Incorporation of Companies with Provincial Objects . . . .
13. Property and Civil Rights in the Province.
14. The Administration of Justice in the Province, including the Constitution, Maintenance, and Organization of Provincial Courts, both of Civil and of Criminal Jurisdiction, and including Procedure in Civil Matters in those Courts.
15. The Imposition of Punishment by Fine, Penalty, or Imprisonment for enforcing any Law of the Province made in relation to any Matter coming within any of the Classes of Subjects enumerated in this Section.
16. Generally all Matters of a merely local or private Nature in the Province.

. . .

Agriculture and Immigration.

95. In each Province the Legislature may make Laws in relation to Agriculture in the Province, and to Immigration into the Province; and it is hereby declared that the Parliament of Canada may from Time to Time make Laws in relation to Agriculture in all or any of the Provinces, and to Immigration into all or any of the Provinces; and any Law of the Legislature of a Province relative to Agriculture or to Immigration shall have effect in and for the Province as long and as far only as it is not repugnant to any Act of the Parliament of Canada.

. . .

108. The Public Works and Property of each Province, enumerated in the Third Schedule to this Act, shall be the Property of Canada.

109. All Lands, Mines, Minerals, and Royalties belonging to the several Provinces of Canada, Nova Scotia and New Brunswick at the Union, and all Sums then due or payable for such Lands, Mines, Minerals, or Royalties, shall belong to the several Provinces of Ontario, Quebec, Nova Scotia, and New Brunswick in which the same are situate or arise, subject to any Trusts existing in respect thereof, and to any interest other than that of the Province in the same.

. . .

THE THIRD SCHEDULE.

Provincial Public Works and Property to be the Property of Canada.

1. Canals, with Lands and Water Power connected therewith.
2. Public harbours.
3. Lighthouses and Piers, and Sable Island . . .
5. Rivers and Lake Improvements.

A third and final initial point should be made. Laws in relation to municipal institutions in a province are exclusively subject matters for the Legislature of that province (s. 92(8) of the Constitution Act). Municipal governments derive their powers from and are subordinate to the province in which they are situate: they are instrumentalities of provincial policy. Thus their role in relation to aquaculture is in a legal sense only that which the province ordains having regard to its policies. A major function of municipal government in Canada today is to control land use. Other functions are largely of a servicing nature, for example, water, sewer, local roads, fire, police, garbage collection. The service functions are closely connected to land use considerations. It strikes me that the most significant thing municipal governments do is to plan for future development in the context of controlling local land and water uses. On this analysis, it is the siting of aquaculture in a municipality that impacts most significantly on traditional municipal functions. I therefore suggest that municipal governments ought to be afforded a role in siting questions. Conversely, I have difficulty seeing any other active role for municipalities to play.

B. SETTING UP

1. Species Selection

A series of discrete, but sometimes interrelated activities are, or ought to be, involved in setting up an aquaculture operation. I would suspect that in the functional ordering of things one of an aquaculturists's first decisions will be species selection. He is probably interested in starting a particular type of operation, be it trout farming, salmon ranching, mollusc or crustacean culturing, or a form of hydroponics. What interest would each of the three levels of government have in this decision?

It seems to me that the main public concern about species selection is the potential impact of any foreign species chosen upon the natural, native biota. It is hard to see the potential harm posed in using a naturally occurring species within its normal range. I do not think, for example, that one could object about the selection of Atlantic salmon as a species to be grown in any of the Atlantic provinces. (This is not to say that there might not be concerns about the gene pool from which seed is selected, or whether the seed carries disease. These matters are dealt with later.) On the other hand, we might judge it unacceptable to allow coho salmon to be cultivated there for fear of the effect that escaping fish might have on wild Atlantic salmon populations. I think we can say the same for the introduction of foreign plant species.[10]

Both the federal and provincial governments would be interested in the potential impact of foreign species. The federal government has constitutional authority over sea coast and inland fisheries under section 91(12) of the Constitution Act (formerly the British North America Act). This embraces authority to protect the natural fisheries from threats posed to it, including that from foreign species. As well, the freshwater fishery as a subject of property ownership falls to the provinces under section 92(13) of the Constitution Act — property and civil rights in the province. Foreign species might prove damaging to provincial property interests, although it is likely that this provincial interest only applies to the freshwater fisheries resource since the marine fishery is considered a public or common fishery not subject to private proprietary interests. It seems to me that municipalities would not have a direct or substantial interest distinct from that of the province. How do we resolve this overlap in interests?

Traditional constitutional doctrines tell us that each government may validly enact legislation to protect its interest in accordance with sections 91 and 92 of the Constitution Act. Should there be no conflict between the legislative provisions, this would mean that each level of government could require its approval as a hurdle before a particular species might be used. If for some reason a conflict arose, the doctrine of paramountcy would apply. Under this doctrine the federal legislation takes precedence and the provincial is rendered inoperative to the extent of the conflict. An example might be federal legislation which prohibited the introduction of a particular species that provincial legislation authorized. In that case, the provincial authorization would be inapplicable and of no effect.

As a practical matter, requiring two approvals, while constitutionally permissible, seems unduly repetitious. Notions of cooperative federalism suggest that the two governments ought to simplify the procedure in perhaps one of two ways. One way might be to set up a joint committee to draw up a common list of acceptable species for particular geographic areas. This committee could likewise deal with novel applications for exotic or non-native species. Each of the provincial and federal governments might enact complementary legislation either to set up the committee and clothe it with decision-making powers, or to adopt, probably by regulations, the mutually agreed upon list. A second way to accomplish this might be to clothe one level of government with the power to make the appropriate selection. This might require a delegation of authority; simple abstention might be sufficient. For example, we might say that the federal government's interest in the marine fishery is the dominant one for marine waters (arguably there is no provincial interest of a legal nature in marine fish) and therefore recognize its exclusive authority to approve the selection of species that may be cultured in marine waters. It may be that no case could be made out for a provincial interest in species selection for marine waters, and therefore it has no authority which we need be concerned about delegating to the federal government. (One might argue for a provincial interest in the anadromous fin fish cultivated in marine waters since they could escape and compete with native anadromous fish in freshwater nursery areas). On the other hand, we might think that the provincial property interest in the freshwater fishery is dominant over the federal interest in that fishery. We might then decide to regard the provincial interest as prevailing to the extent that it be the sole decision maker concerning species to be cultured in fresh water. In this case federal legislation adopting the provincial selection might be desirable.

Such methodologies would diminish the administrative hurdles facing a would-be culturist by reducing the two possible decision makers, each of whom carries a veto and each of whom would likely have to be separately consulted, to one in number. Some might argue that this seemingly complex system is worse than the disease it was intended to cure. Certainly there will be initial short-term problems in setting up the system, but it strikes me that it would, in the long-term, benefit aquaculture development. I suppose it would be fair to comment that intergovernmental wrangling would substitute for government–private business wrangling to some extent. I should also add that I see a potential for such a consultation and delegation system resolving many more issues than simply species selection. Short-term wrangling followed by some measure of clarification and certainty seems preferable to longer-term ambiguities. It may be however, because of the hard, immediate negotiating required, that my suggestion is doomed to failure.

2. Site Selection

Continuing on with this line of inquiry, another important decision for the culturist in setting up his operation is the selection of a physical site. He will no doubt have his reasons as a student of the technical aspects of aquaculture for selecting a particular site: the advantages of the site he wants are obvious to him. Arguably if he errs in his selection he has only himself to blame, and perhaps we ought not to be concerned about this. (One might argue that all aquaculture failures reflect poorly on the industry and inhibit new entrants; for this reason we might try to protect a culturist from his own folly.) But it is also quite possible that a culturing operation will pose conflicts with other activities. Similarly, even though no conflict exists today, when the operation is set up, subsequent events might impose a negative impact upon the culturist. A closely allied point is that prime aquaculture sites are in limited supply, analogously to the supply of farmland, and that the public ought to be concerned about protecting these favoured sites from conflicting activities even where no aquaculture operation is presently proposed. Thus site selection is closely tied to land, water, and coastal zone planning and resources management.

From a provincial standpoint the central feature in this planning and management activity is its real property connection. The province owns its ungranted land mass, its freshwater resources, the subaquatic lands underlying its lakes and streams (with the exceptions of New Brunswick and Prince Edward Island, where riparian ownership continues), and the seabed and subsoil underlying marine waters within its boundaries. The federal government would, by virtue of section 91(1A), have legislative control over real property owned by it within provincial boundaries, examples being national parks, certain public harbours, most airports and national defence establishments. The province, with the exception of this federal public property, has full legislative authority by reason of section 92(13) — property and civil rights in the province — over private and public lands within provincial boundaries. Thus, with rare exceptions, an aquaculture operation will be located in an area whose property aspects give the province a substantial constitutional interest.

Municipalities also have a substantial interest of a traditional nature in the location of aquaculture sites. The provinces, which are accorded constitutional authority by section 92(8) of the Constitution Act over municipal institutions, have delegated to municipal governments, including cities and towns, areas of responsibility for local affairs, a chief component of which is the way land is used. Thus all provinces have statutes similar to the Planning Act[11] in Nova Scotia which authorize legally relevant municipal land-use plans and municipally enacted zoning by-laws to regulate land use. Land planning invariably entails water and coastal zone planning as well, although these may be accorded a secondary position. It should also be appreciated that while aquaculturing takes place in an aqueous medium, it usually requires a close tie to a land base. Thus, even putting aside the municipal interest in water resources, the legitimate interest of municipal units in land use requires some degree of municipal involvement in aquaculture siting. This interest provides, in my view, the main, if not the only, justification for a municipal role in aquaculture.

The constitutional interest of the federal government in aquaculture siting seems to be two-fold: federal public property may be involved; the aquaculture operation might pose a conflict with other activities under federal legislative control. The first interest, as I have already indicated, stems from federal legislative jurisdiction conferred by section 91(1A) of the Constitution Act — the public debt and property. The second interest stems from federal legislative jurisdiction over activities whose conduct may be inconsistent with aquaculture. Thus, Parliament has control over navigation and shipping (s. 91(10)), beacons, buoys, lighthouses and Sable Island (s. 91(9)), the militia, military and naval service, and defence (s. 91(7)), sea coast and inland fisheries (s. 91(12)), ferries between provinces or to foreign countries (s. 91(13)), Indians and lands reserved for the Indians (s. 91(24)), and interconnecting extraprovincial undertakings like most railway, shipping, and pipe lines (ss. 91(29) and 92(10)).

It seems to me that in the best of all possible worlds we might resolve the problem posed by these potentially conflicting jurisdictions by a comprehensive, cooperative planning exercise based upon a fully comprehensive resource inventory. This exercise, while cooperative and consultive, must nevertheless entail recognition of where the legal powers lie. Thus, if a resource survey identified a specific site as particularly suitable for aquaculture but the federal government thought it expedient to establish docking facilities and shipping lanes with buoys and markers in the middle of it, their exercise of jurisdiction is paramount: the area would be used for shipping and navigation. If aquaculture can live with this so much the better; if it cannot it must move elsewhere. If this is unacceptable to the province then it has powers of persuasion open to it. But in the final analysis it is the federal power which wins the day.

If all these problems can be ironed out in advance then at least those areas which remain undesirable for federal purposes will remain for aquaculture, we hope. Again there is no guarantee of this. Should a federal need only arise later, after an aquaculture site is operative, it as well takes precedence, although questions of compensation to the culturist would likely arise. Recognizing this federal preeminance makes it vital at the outset that planning take place. We as a society should ensure that, so much as is possible, each activity is located to its best advantage with a minimum of undesirable impact on others. Rationality suggests that this can best be done by identifying natural capacities in advance and cooperatively deciding on locations. Once federal–provincial consultation has dealt with the generalities of location, it then remains for provincial–municipal consultation to resolve the specifics of location so as to tie into municipal planning and zoning schemes. There may also be issues of infrastructure, like the creation of aquaculture parks similar to industrial parks, and of rural community and economic development to be ironed out between municipal governments and the provinces, perhaps with federal financing.

3. Seed Stock

With a species and a site selected and assuming the construction of the necessary facilities and the purchase of suitable equipment, the remaining concern of the aquaculturist in setting up his operation is the acquisition of seed stock. Since the species has already been selected, the key concerns now with seed are three-fold: disease, parasites, and genetics. The federal interest is the danger which these factors pose for the native fishery. The cultivated stock might escape and mix with the wild; perhaps the intermixing of water used in culturing with natural water bodies will carry these factors to the wild stock. The problems posed to wild stock by disease and parasites are obvious; the genetic factor is more subtle. Simply put, strains of stock genetically suited, indeed genetically engineered, for culturing purposes may weaken the desirable genetic make-up of wild stock. The province as property owner (the freshwater fishery and the provincial land/water base) likewise has an interest. Its fishery concern may be legally limited to fresh water and the balance of its legal interest may be in the ecosystem and its protection. It may be that the plenary nature of the federal interest coupled with the partial (freshwater fishery) and indirect (ecosystem) nature of the provincial interest would militate in favour of federal control over inspection and approval of seed stock. However, since many provinces have administrative control over their inland fisheries resources, it may make more sense to let control over the issue of protecting native stock follow administrative jurisdiction over that of wild stock.

4. Water Supply

Another key concern in setting up an aquaculture operation is the availability of a suitable water supply and the requisite subaquatic land/surface land base through which to use the water. Obviously land itself can be acquired from its owner, be it public or private, on a full purchase or lease arrangement. The water itself breaks down legally by virtue of whether it is fresh or salt: fresh water (neglecting problems of water in international and interprovincial rivers and that contained on federal lands) is a provincial resource; salt water as a substance is not owned by anyone until physically appropriated, but can be viewed as subject to the control of the entity owning the seabed underlying it. Subaquatic land ownership and control, including the seabed and ocean subsoil, as subjects of property, reside in the province or federal government depending principally upon whether the areas fall within provincial boundaries. In other words, unless the province has conveyed the land away, it belongs to Her Majesty in right of the province. If the province has conveyed its interest to the federal government (as in a National Park or public harbour) or the Federal authorities have otherwise acquired it (as for example by purchase or expropriation) then the subaquatic lands and control of the superjacent water resource belong to Parliament as federal public property. Additionally, the province may have granted the subaquatic lands to a private individual, but while legal ownership may be in private hands, legislative jurisdiction over the lands remains in the province. Thus the key matter in relation to a water supply is legislative control over the lands from which the supply is derived. In this connection the control of freshwater supplies is reasonably clear. The area of controversy surrounds marine waters and the extent to which provincial boundaries extend into such areas. For example, how far into the offshore does the boundary of Nova Scotia extend? A vital but seldom recognized point should be noted. There is an area in marine waters which almost certainly falls to the provinces. This forms part of an area technically termed "inland waters". Inland waters are not just those waters inland of the land/sea interface (i.e. landward of the tidal margin); they encompass the area inside a baseline which connects up points along the coast. Thus, many bays and most coves, inlets and estuaries are included as inland waters. The baseline used is, I believe, the same one used in international law to calculate the territorial sea and the exclusive economic zone. Thus, in the leading case on the extent of provincial jurisdiction in the offshore, the *Reference Re Offshore Mineral Rights of British Columbia*,[12] the question submitted to the Supreme Court of Canada specifically excluded "the harbours, bays, estuaries and other similar inland waters".[13] As well, a case now before the Supreme Court seeks to determine whether the Strait of Juan de Fuca, the Strait of Georgia, Johnstone Strait and part of Queen Charlotte Strait are inland waters and so part of the province of British Columbia.[14] Thus, with the exception of the issue of how far provincial boundaries extend into the offshore, questions of water supply should not pose major constitutional conflict.

5. Leases

The question of what areas are owned by the province is relevant to another concern of the prospective aquaculturist: who can grant or lease to him subaquatic lands, or a licence to occupy such lands. In other words, most culturing operations will be physically situated in a body of water and the culturist ought to have acquired sufficient rights from someone to entitle him to occupy that space. That right should be conferred by the entity owning the area in question, which would usually be the province. One should also bear in mind federal control over navigation and so the need to comply with any requirements for permission from federal authorities before an installation can be placed where it might interfere with navigation.[15] It should also be noted that the logic of this scheme has been disrupted by some delegations by the provinces to the federal government of authority to lease areas for oyster culture.[16] Royalties ought persumably to follow ownership of the resources being leased and used.

6. Licences

A difficult question in this anlaysis of the structural framework within which a culturist must set up his operation is that of licencing. One way of approaching this question is to ask who has jurisdiction over aquaculture as an activity. This is the question which I asked and dealt with in an earlier work.[17] My view then and now, although not unequivocal, was that the essential feature about aquaculture is its private property relationships. Thus the organisms being cultured are subjects of private personal property, the siting questions are fixed to real property interests, and utilization of water is an aspect of property management. The provincial interests in these areas are central. The federal interest in the stock as fish (at least in the general case) cannot readily be equated to the federal fisheries power since that power does not include property ownership; the federal fisheries interest is likely restricted to the possible impact of the operation on the wild fishery stock. Thus, in my view, the general licence to conduct aquaculture ought to be granted by the province where the operation is to occupy property under provincial control. This would not, however, as has been previously emphasized, preclude aspects of federal control, for example, over the possible introduction of exotic species or diseases, or interferences with navigation. Similarly, if the operation is to occupy federal Crown property, I would think a federal licence, as well as a lease, would be the appropriate tool. In this latter connection, though, I would think that the aquacultural stock, as private personal property and not as federal public property, would be subject to provincial property laws. Thus provincial personal property legislation might be needed to protect the property interest of a private operation in this stock, even if operating on federal lands with a federal licence. One might, in both these connections, think about a joint licence-approval process, or making the licence the final step in the process, predicated on having secured all other necessary approvals.

7. Finances

Of additional importance in setting up an operation are questions of finance. I suppose an appropriate attitude, certainly for the culturist, is "the more the better." One would expect that all levels of government would have an interest in assisting development and could do so by assisting in its financing. One would also expect that in terms of providing grants, loans, and financial incentives to the culturist there would be little scope for conflict between governments. One potential area of conflict though is in relation to priorities amongst various security holders should it be necessary to close down the operation due to bankruptcy or insolvency. Possible conflicts between provincial control over private property rights (s. 92(13)) and federal control over federal public property (s. 91(1A)), banking (ss. 91(15) and 91(16)), bankruptcy and insolvency (s. 91(21)), and the borrowing of money on the public credit (s. 91(4)) are relevant. These questions are really wide and far-reaching, encompassing a substantial portion of the realm of commercial law. It is not simply a matter, even if this were financially realistic, of saying that the federal government could finance operations on their lands while the province could do the same for provincial lands. It is complicated by the presence of banks and other private lenders and the range of possible security documents. Aquaculture would not be, to my mind, a suitable vehicle for clarifying this complicated area. Suffice it to say that some financial assistance should be available to culturists and policy makers ought to be advised of pitfalls to avoid. Further work in this area might be appropriate.

C. OPERATING

1. Environmental Protection

Now that our hypothetical, general aquaculturist is set up as a going concern, one pertinent issue to his continued operation is that of environmental protection. This has two aspects: protecting the operation from external threats (e.g. municipal sewage) and protecting others from threats posed by the operation itself (e.g. fertilizers, fish waste). Again the federal interest is in protecting the wild fishery. I suggest that this does not extend to protecting the aquaculture stock, which is more properly regarded as private property. The legal interest of the province is directed to the aquaculture stock as private property, and to the entire array of provincial interests in the health of its natural resources. The interrelationship of these issues has been worked out in a broad sense already in the field of environmental protection, although perhaps not entirely satisfactorily. This relationship is essentially premised on the view that the provinnce has primary responsibility, while the federal role, taking precedence in areas of conflict, is of a specialized nature. No federal pollution licencing scheme exists in Canada which would burden an aquaculture operation. Thus, provided the general prohibitions like section 33 of the Fisheries Act are honoured, there is no direct federal involvement. A provincial licence would often be required. Again, it may be a question of the tail wagging the dog if we approach aquaculture as the medium for ironing out federal–provincial cooperative roles in environmental protection. A better case might be made for improved provincial–municipal cooperation. Municipal development activities have a considerable potential for degrading the environment, and while in large measure the legal controls are in place, it may be that greater adherence to these standards by the municipalities would be in order.

2. Fish Health

Another concern of the operating culturist is the health of his stock. We have already discussed questions of disease and parasitism in relation to their possible introduction through seed, and the nature of the concern here is the same. Perhaps the major distinction between the two situations is the fact that if the stock of an operation becomes infected it may become necessary to destroy the stock, imparting a crippling financial blow to the culturist. This dramatic effect is capable of being ameliorated through insurance or compensation, which either level of government could set up. My inclination is to regard the federal interest in assuring no spillover affect paramount.

3. Taxation

Taxation is a concern relevant to the financial attractiveness of aquaculture. It is also an area in which all three levels of goverenment have an interest, and in which all three do, and no doubt will continue to, make their cumulative impact felt. Provincial–federal delegation is not likely, as each government will want to maintain its position. Again there is no point in repeating what I have said elsewhere, except to emphasize two points. First, it is hard to justify not placing food-producing aquaculturists in the same situation as farmers and fishermen. Second, real incentives to aquaculture could be provided by appropriate adjustments to income tax, customs duties, real property assessments, business occupancy tax, and the myriad other forms of taxation.

4. Theft

Of fundamental importance to the operating culturist is the extent of the legal protection afforded to his property interest in the stock. We have already dealt with the capacity of the province to legislate in relation to personal property rights in the stock. Mention ought as well to be made at this juncture to a parallel concern — the protection of the stock from theft. The creation of a criminal offence like theft is an aspect of the federal criminal law power (s. 91(27)). The protection the Criminal Code confers on oyster beds and fur farms could easily be extended to all aquaculture stock, although it is likely necessary that the underlying personal property rights be first created or clarified by the provinces. It is arguable, of course, that if provincial law clearly defined a culturist's personal property rights then the general offence of theft itself would cover loss of a culturist's stock. However it strikes me as desirable not simply to rely upon this but rather to specifically state in the Criminal Code that taking aquaculture stock was theft and that breaking open a culturist's cage, net or pen was the offence of break and enter.

D. MARKETING

The constitutional problems surrounding marketing of aquacultural produce are merely aspects of the problem of marketing any product. The guiding principles can be easily stated: aquacultural produce as an extraprovincial (meaning interprovincial as well as international) trading commodity is subject to federal control under the federal power over the regulation of trade and commerce (s. 91(2)); the produce as a local, intraprovincial trading commodity is subject to provincial control as a matter of property or civil rights in the province (s. 92(13)) or as a matter of merely local concern (s. 92(16)). Concerns of quality control of the product, methods of preparation, inspection of the fish and of the processing facility, and labelling of the packages follow the distribution of powers in accordance with whether the product is for the local market or the extraprovincial market. The rub is in deciding when something can be considered part of extraprovincial trade. Obviously this would be the case when the processed product is packaged and loaded on a truck bound for the United States, but what about when the produce is undifferentiated as to destination, and yet we know some percentage will go outside the province and some will stay in? This would normally be the case throughout the processing stage for a plant which serves both local and foreign markets. Does it matter if the percentage bound extraprovincially is 90%, or only 10%?

These problems could well be handled through cooperative measures. The federal government clearly has an interest in quality assurance in order to protect Canada's reputation abroad and hence the receptivity of others to our produce. Similarly the federal government is the one in the best position to insure that poor products from one province do not damage the prospective sales of another province. This interest is to me a stronger one than the interest of the province in protecting its citizens from unsafe or poor products when one considers that the concerns of the federal authorities are similar. Hence, I would see a case for delegation of administrative authority over these aspects by the province to the federal government. Why have parallel systems of inspection or of processing? Hopefully, not simply to show parochial provincial colours.

E. CONCLUSION

Each of the federal and provincial governments could go it alone in the aquaculture field. We would be undoubtedly worse off for it, if for no other reasons than because of conflicts that will likely arise from siting questions and duplications of effort that will arise in areas like species approval and fish health inspections. How much worse off aquaculture would be is difficult to say. We can at least comment that in the best of all worlds we would not choose to deal with jurisdictional problems by ignoring them.

The will to solve these problems may not come without a sense of urgency. Perhaps this will come from frustration over opportunities being thwarted; perhaps from excitement over future prospects. The existence of this, the National Aquaculture Conference, says something about the importance of this subject and will no doubt be a generator of heightened interest both about and within the aquaculture industry. Maybe the time is ripe to consider building on this momentum; maybe a Canadian version of the American National Aquaculture Act of 1980 should be the focus.

It is perhaps trite to reemphasize a very common theme in all economic and industrial contexts: the need for planning, research, and development. I see it as a federal role, under our constitutional and political structure, to provide the major stimulus in these areas. Here note must be taken of the so-called spending power. By this expression reference is made to the fact that the federal government, or the provincial for that matter, has no limit on the areas in which it may spend its money: the federal government can spend money in areas under provincial jurisdiction, and *vice versa*. It might, for example, loan money directly to culturists or purchase prime land and water areas for protection reasons. Of course, this idea must be coupled with the constitutional principle that the federal taxation power is unlimited and the political reality that federal–provincial tax sharing agreements give the lion's share of the tax revenue to the federal government. Thus, in short, the federal authorities have the legal and fiscal capacities to provide an expansionary stimulus. I know that this is easy to say and that it leaves unanswered questions of specifics. But you will recall that the American legislation did not address the specifics either — it simply appropriated money and set up a planning and coordinating framework. Surely we can at least do that. I hope that this framework will as well set up the mechanism for solving, on a province-by-province basis, problems of a federal–provincial nature. Let us assist the process of Canadian industrial development by encouraging aquaculture to reach its potential through a constructive federal–provincial cooperative problem-solving exercise.

NOTES

[1] T. Williams, "Exotic Cohos Versus Atlantic Salmon," *Atlantic Salmon Journal* 29, 4 (1980): 20.

[2] B. H. Wildsmith, *Aquaculture: The Legal Framework* (Toronto: Emond-Montgomery Ltd., 1982) p. 132.

[3] In an earlier work, *Aquaculture: The Legal Framework, supra* note 2, I dealt with the constitutional division of powers in relation to aquaculture: see p. 33–91, esp. the discussion of federal powers p. 71–81. This paper differs from the analysis there in organizing the discussion on a functional basis and then suggesting something of how the respective powers and interests of each level of government might be integrated on a cooperative basis into a comprehensive and lawful whole.

[4] This might be done by the delegation of administrative authority from one level of government to the other. Note that there is a constitutional prohibition on the delegation of legislative power from the provincial government to the federal government and *vice versa*. See *A.G.N.S* v. *A.G. Can*. (Nova Scotia Interdelegation Case), [1951] S.C.R. 31 and the discussion in P. W. Hogg, *Constitutional Law of Canada* (Toronto: Carswell, 1977) p. 332–37.

[5] I do not profess expertise in the very complicated field of American constitutional law. These conclusions are derived from Gunther, Gerald, "State Control of its Natural Resources" in *Cases and Materials on Constitutional Law* (10th ed., Mineola, N.Y.: The Foundation Press, 1980), p. 326–32; *Resources From the Sea and Federal Limitations on State Control*, Maine Law Affecting Marine Resources, Volume Four (Portland, Me: University of Maine School of Law, 1970), p. 639–41; Bowden, Gerald, *Coastal Aquaculture Law and Policy: A Case Study of California* (Boulder, Colo.: Westview Press, 1981), p. 33–39, 153–54; Submerged Lands Act, Pub. L. No. 83–31, 67 Stat. 20 (1953); *U.S.* v. *Louisiana et al*. (1960), 364 U.S. 502.

[6] (1979), 441 U.S. 322.

[7] *Aquaculture in the United States: Constraints and Opportunities*, A Report of the Committee on Aquaculture, Board on Agriculture and Renewable Resources, Commission Natural Resources, National Research Council (Washington, D.C.: National Academy of Science, 1978), p. 75.

[8] Pub. L. No. 96–362, 94 Stat. 1198.

[9] The Legislative History to the Act refers to H.R. 370 introduced in the 94th Congress on which eight days of hearings were held, followed by Subcommittee research efforts and the introduction of H.R. 14695 in the same Congress. An identical bill (H.R. 1833) was then introduced in the 95th Congress, followed by hearings and submissions and a revised bill (H.R. 9370). This form passed both the House of Representatives and the Senate but was vetoed by the President on October 19, 1978. In response to the President's concerns, H.R. 20 was introduced in January 15, 1979. This bill was reported to the House by the Merchant Marine and Fisheries Committee and the Agriculture Committee. Meanwhile a parallel bill, S. 1650, was proceeding through Senate, it being reported on by the Commerce, Science, and Technology and Agriculture, Nutrition and Forestry Committees. The House and Senate Bill were amended to conform and this version was passed by each in September, 1980 and signed by the President on September 26.

[10] The distinction between fish and plants has a constitutional significance — arguably plants are not embraced by the federal fisheries power. Aquatic plants, like the forestry resource, should only fall under the control of the federal government if they are growing on federal public property. It is difficult to see how the federal government could require its approval before non-native plants are introduced in the aquatic environment unless the place of introduction was federally owned or a good case could be made out for the need to protect federal lands or the fishery from the adverse affects that the plant would have. An arguable case can be made out to suggest that most marine waters and all fresh water where plants might be cultured are provincially owned or controlled. See B. H. Wildsmith, *Aquaculture: The Legal Framework, supra* note 2, p. 61–71, 101–03.

[11] S.N.S. 1969, c. 16.

[12] [1967] S.C.R. 792.

[13] *Ibid*, at 792.

[14] The British Columbia Court of Appeal held that these areas were part of the province: *Reference re Ownership of the Bed of the Strait of Georgia and Related Areas* (1976), 1 B.C.L.R. 97.

[15] See the Navigable Waters Protection Act, R.S.C. 1970, c. N-19, and regulations thereunder.

[16] See, e.g., the 1936 Mollusc Agreement between the federal government and Nova Scotia: B. H. Wildsmith, *Aquaculture: The Legal Framework, supra* note 2, p. 75–76.

[17] B. H. Wildsmith, *Aquaculture: The Legal Framework, supra* note 2, p. 33–61.

OPPORTUNITIES AND CONSTRAINTS IN THE MARKETING OF AQUACULTURE PRODUCTS

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ABSTRACT

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Although per capita consumption of seafood in North America has been stagnant over the past decade there are indications that demand conditions are favourable for certain types of products. In particular, fresh seafood has experienced a rise in demand from a consuming public increasingly aware of health and fitness. The conventional commercial fishery has, in many countries, responded to this shift in consumer preferences by improving and stabilizing the quality of seafood and altering the product-mix of their output toward fresh products. Nevertheless, structural deficiencies in the harvesting and processing sectors of the conventional fishery have limited its ability to fully exploit the demand for high quality fresh and frozen seafood.

These demand and supply conditions create a market opportunity for the aquaculture industry. Unlike the conventional fishery it can control the size, quality and, in many cases, timing of the product it delivers to market. Characteristics such as flesh colour can sometimes also be altered to respond to perceived preferences of consumers. These advantages of aquaculture can offset the relatively high cost of farming fish and give farm-raised products a competitive advantage in the market place. A clear illustration of the successful exploitation of the market opportunities inherent in farming fish is the growth of salmon farming in Europe — notably Norway.

The advantages of fish farming are offset by several important constraints. The high cost of farming fish relative to conventional harvesting may limit the type of product which can be profitably sold. The lack of knowledge about seafoods on the part of consumers, the questionable reputation of the conventional fishery in supplying a product of uniform quality, and the need to establish new distribution channels, all pose formidable marketing challenges to the aquaculture industry. These and other problems facing the aquaculture industry could limit the development of the industry despite the existence of lucrative markets.

Many of the potential difficulties of the aquaculture industry can be overcome through cooperative behaviour of firms within the industry. Such behaviour has been demonstrated in European countries where salmon farmers have organized to fund consumer research and advertising, to monitor and control product quality and to create a brand image for their product in the marketplace. An additional advantage of organization — to control the supply of a product put on the market — has not been pursued in Europe. This has led to fears that a glut of farmed salmon will appear within the next 5 years, leading to depressed prices and bankruptcies in the industry.

DEMAND CONDITIONS FOR SEAFOOD PRODUCTS

> "The American diet is changing as people become more concerned about health and fitness. That should mean long-term gains in the per-capita consumption of seafood. The key question: Is the industry doing enough to capitalize on current daily dietary trends and on the healthful qualities of seafood?"[1]

The strong demand for fish products is reflected in the fact that fish prices rose more quickly than other sources of protein over the past decade. The recognition by the public of the healthful character of fish relative to important substitutes, combined with real income growth in the United States and Canada, has stimulated demand for seafood products. The price rise has slowed in recent years due to lower prices of substitutes, increases in domestic supplies in the United States and Canada and recent declines in real income.

The increasing preference for seafood has not been shared evenly by all products. As stated in the Kirby Report in reference to demand conditions for groundfish products:

> "There has been a strong shift in consumer preferences away from the 'heavy' breaded and battered products made from blocks and toward lighter, more 'natural' products, primarily fresh and frozen fillets"[2]

The Kirby Report goes on to document the dramatic increase in the consumption of the fresh groundfish in the United States in the face of relatively stagnant growth in the consumption of other groundfish products. For example, between 1977 and 1981 consumption of fresh groundfish in the United States rose by 47% compared to only 6% for all groundfish products. Perhaps even more significant is the projection that consumption of fresh fillets is anticipated to jump by another 43% by 1987.

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[1] *Seafood Business Report*, Vol. 81, No. 1, Winter 1982, p. 4.

[2] Kirby (1982), p. 129–130.

This data on consumption patterns for groundfish is reinforced by reports on seafood markets in both North America and Europe. The growth of salmon fish farming in Europe and the sudden growth in sales of European farmed salmon to North America are based on supplying a fresh product year-round. "Some 90 per cent of Norway's farmed salmon is exported and 85 per cent of this is distributed fresh, on ice."[3] Reports that sales of fresh fish are booming at the retail level in the United States are found in every seafood publication with glowing reports such as the following,

> "'The biggest thing we have going for us here is fresh,' maintains Jim Reffel from Seattle Fish. 'The demand for fresh has grown phenomenally in the last year and a half. Everyone wants fresh.'"[4]

RESPONSE OF THE CONVENTIONAL FISHERY

Changing consumer preferences combined with technological advances in refrigeration and transportation systems offer greater potential to the seafood industry than in previous times. Firms involved in the conventional narvest of natural fish stocks have been attempting to meet the challenge posed by increased demand in a variety of ways:

1) The level and consistency of product quality have received a great deal more attention and large sums of money are being allocated to upgrading the quality of seafood products.

2) Mass promotional campaigns are being pursued in many countries including the United States and Canada to reinforce, in the minds of the public, the superiority of fish as a source of protein. The relative unfamiliarity of the public with seafoods is the focus of this advertising.

3) Canadian fish processors have shifted towards producing products offering price premiums. "In response to these changing market opportunities, the product mix of Canada's Atlantic groundfish industry changed over the period between 1977 and 1981. The major changes were an 11 percentage point shift toward the production of salted products and a 19 percentage point shift out of cod blocks and into fresh and frozen fillets."[5]

4) Transportation, storage, and packaging of seafoods have been improved and utilization of new methods has increased the speed of delivery along with the quality and appearance of products upon delivery.

INADEQUACIES OF THE CONVENTIONAL FISHERY

Despite these efforts per capita seafood consumption in both the United States and Canada has been relatively stagnant and a significant market breakthrough has not been achieved. Explanations for this failure are the following:

1) Structural deficiences in the harvesting and processing industries have kept both sectors near the bankruptcy level. Excess capacity in the harvesting and processing of fish products has raised industry costs well above minimum levels and decreased the ability of the industry to capture a larger market share through price competition. Increasing fish prices are needed to merely maintain the financial viability of the fishing industry. Low profit levels have also reduced the amount of money available to invest in promotional campaigns or equipment to speed delivery and improve product quality. The ability of the industry to respond to and take full advantage of potential profits offered by changing consumer preferences has thereby been reduced.

2) Fish processors cannot, in general, control the quality or size of the landed product. Competition by fishermen for a large share of total catch and by processors for fishermen's loyalty results in a low level of quality in the landed product in spite of the dictates of the market place. Potential sales to consumers demanding a product with specific attributes (i.e. fat content, firmness of flesh, etc.) are lost. Also, the processing options available are limited by the quality and size of the landed product decreasing the processors' ability to break into markets for new and potentially profitable products.

3) In many cases the processor cannot control the timing of landings from fishermen. The inherent seasonality of many fisheries is exaggerated by competition among fishermen to obtain a large share of the total available catch. The resultant concentration of landings increases the processing capacity and storage space required to process a given quantity of fish. The costs associated with providing this capacity limit the processing options of a firm and may result in a final product mix different than if a more even supply of fish were provided. That is, even if a premium product would generate greater revenue for a processor, the cost of acquiring the necessary processing capacity, which would be used for a short period of time, could be so high as to make it unprofitable to move into this product line.

The seasonality of many natural fisheries has further negative implications for the marketing of fresh seafood. A fresh product can only be supplied for a portion of the year. This has become more of a problem as consumer preferences have shifted increasingly toward fresh fish and is more serious because the supply of fresh fish often does not match consumption patterns. "In North America, there is a major drop in consumption for all types of fish in the summer months, when Canadian catches are high."[6] The seasonality of supply for fresh fish has been an important drawback in developing a strong demand for fresh fish products. According to a marketing specialist for a large retail outlet in the United Kingdom, "We have to base our business on regular supplies... If a customer buys a product one week and returns the next week to find that it isn't available she will switch to something else."[7]

A steady, year-round availability of a product such as fresh fish is crucial in its attempt to compete with substitutes, such as poultry, for a regular place in the consumers' menu. Year-round supply would also be an important factor for fresh seafood to gain a place on the shelves of supermarkets. Fluctuations in availability put seafoods at a distinct disadvantage in competing for shelf space with substitutes which can be supplied year-round.

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[3] *Fish Farming International*, Vol. 9, No. 4, June 1982, p. 4.

[4] *Seafood Business Report*, Vol. 81, No. 1, Winter 1982, p. 42.

[5] Kirby (1982), p. 130.

[6] Kirby (1982), p. 152.

[7] *Fish Farmer*, Vol, 5, No. 5, May 1982, p. 6.

4) For many fresh and frozen seafood products, it is not possible for firms to differentiate their products from those of their competitors. This is particularly true for small firms which may not market their own products. As a result, it may not be possible for firms who supply a consistently high quality product to receive a price premium for doing so. The advantages of supplying consistently high quality products are therefore lost. Furthermore, undifferentiable products imply that there is little advantage for a firm to invest in advertising and promotion since any benefits from doing so will be spread through the entire industry and not captured by the firm which makes the investment.

5) The decimation of many natural fish stocks, such as the Atlantic salmon, has meant that the conventional fishery has not been able to capitalize on the potential demand for these products.

OPPORTUNITIES FOR THE AQUACULTURE INDUSTRY

While the problems of the conventional seafood industry have constrained the ability of the industry to take advantage of the emerging market potential, they also provide advantages to a properly organized aquaculture industry. These advantages can be described as follows:

1) A fish farming operation has direct control over the product. Quality can be monitored and controlled as can the size and many other characteristics of the product including flesh colour, fat content, etc. A fish farm operator who is aware of what type of product is preferred by the consumer can run his operation accordingly. The difficulties of conventional processors in supplying the type product preferred by consumers is eliminated. As put by a major Scottish salmon farmer, "Rather than saying to potential buyers that we have salmon which we are ready to sell and this is what we can supply, we've tended to say we're in the salmon business, now what do you want from us?"[8]

2) Fish farms are often capable of supplying a specified quantity of a given product year-round at a preestablished price. For fresh fish products this consistency of supply is crucial in inducing consumers to include the product as a regular item in their menus. Not only can farmed products take advantage of the seasonal decline in supplies of fresh products from the conventional fishery by supplying fresh fish year-round but consistency of supply is vital in convincing major retail outlets and franchise restaurants to carry fresh fish. In discussing this issue as it relates to the groundfish industry the Kirby Report made the following observation. "Particularly for seafood speciality restaurants, which sell a large proportion of the groundfish consumed through the public food service sector, a guaranteed year-round supply is essential."[9] This point was reinforced by an article in the Pacific Packers Report. "Restaurateurs are adjusting to the shift (in consumer preferences) as they demand fresh, quality seafood first, a steady supply second, with price factors ranking third."[10]

It is instructive at this point to identify a case where the advantages of farmed fish products have been demonstrated in the market place. The most striking example is the success of pen-reared salmon in Scotland and Norway. This success can, perhaps, be best illustrated by the recent Norwegian penetration of the United States market. In the first 9 months of 1982 the United States imported 611 000 lb of fresh salmon worth $2.2 million. This compares to imports of salmon totalling 83 000 lb worth $327,000 for all of 1981.

The move into the United States is a natural extension of the rapid rise in the popularity of farmed salmon in Europe which has spurred increases in production in many European countries, particularly Norway and Scotland. The popularity of farmed salmon in Europe was explained as follows in a 1980 Sea Grant study. "It was stressed that this farmed salmon was well-liked in European markets for its uniformity, quality and freshness. Freshness in seafood is very important to the European consumer; the fact that Norwegian farmed salmon are killed, cleaned and chilled immediately and shipped directly to the buyer make them a much more preferred product than frozen Pacific salmon."[11]

The decimation of Atlantic salmon stocks created a market opportunity which was reinforced by the seasonality of fresh supplies of both Atlantic and Pacific salmon from the conventional fishery. European salmon farmers took full advantage of this opportunity by providing a product which met the demands of consumers. Their success is illustrated by their entry into the United States market a a time when landings in Alaska reached historically high levels.

CONSTRAINTS ON THE DEVELOPMENT OF AN AQUACULTURE INDUSTRY

The opportunities offered aquaculture products in the market place are offset by several important constraints:

1) For many species we have little or no experience in artificially breeding and raising fish stocks. The acquisition of such knowledge is expensive. Appropriate measures to ensure disease control and that the fish raised is acceptable to consumers add to the expense of fish farming.

2) Even when techniques for raising fish are perfected, the costs of holding and feeding fish for long periods of time put farmed fish at a disadvantage relative to those caught in the wild. This is particularly true for species which are high on the food chain and may add only 10–20% of the volume of food eaten to their body weight. While this disadvantage may be offset by high egg to adult survival rates and rapid growth, the relative expense of fish farming may dictate that products enter a different market niche than their wild counterparts. In particular, the ability to control quality and supply a fresh product year-round can be exploited to capture the high-valued fresh fish market. It is important to remember that this disadvantage will decrease through time as technologies and farming methods are perfected and large operations, enjoying economies of scale, emerge.

3) The knowledge of fish products on the part of consumers is low, ". . . recent research indicates that consumer knowledge of seafood products is extremely limited when compared with their knowledge of other proteins. This contributes to a lack of confidence and reduces the probability

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[8] *Fish Farmer*, Vol. 5, No. 7, Sept. 1982, p. 36.

[9] Kirby (1982), p. 133.

[10] *Pacific Packers Report*, Vol. 79, No. 2, Fall 1982, p. 7.

[11] *Aquaculture Magazine*, Vol. 8, No. 4, May/June, 1982, p. 34.

that consumers will buy and prepare fish at home."[12] What may be more problematic for the aquaculture industry is that the knowledge consumers do possess of fish products comes from purchasing products from the conventional fishery with its serious problems of achieving consistently high quality products.

It is, of course, possible to correct this situation through advertising the benefits of fish consumption and the merits of farmed products relative to their natural counterparts. Financing such as advertising campaign could, however, be prohibitively expensive, particularly for a small fish farmer.

4) There are no established distribution channels exclusively oriented to the marketing of aquaculture products in Canada. The export oriented nature of the Canadian fishing industry has resulted in a deemphasis on domestic marketing channels. To create an effective distribution system would be extremely expensive for an aquaculture firm. The alternative is to funnel distribution through existing food distributors. As put by one Scottish salmon farmer:

> "We recognized from the outset that we couldn't have our cake and eat it in this business, so we've decided to be specialists in processing and packaging, and leave the selling to our prime trade customers. We are already developing links with one or two companies who have established food products of their own and therefore have a well-tried network of distributors, salesmen and stock control."[13]

Enlisting the support and cooperation of food distributors would take a well coordinated effort as they would have to be convinced as to the advantage of farmed fish products. In particular, misconceptions about the quality and availability of seafood products created by the conventional fishery would have to be broken. A special challenge would be to capture a place for fresh fish on the shelves of large food retailers. The difficulty in doing this can be illustrated by a quote from one large retailer, "When you're used to selling frozen seafood, fresh is so much more work and trouble, you delay doing it as long as possible."[14]

5) A single firm in the aquaculture industry is unlikely to be sufficiently large to afford the expense of creating a brand image for its products. Given this, and the difficulties of differentiating the source of fresh fish products, a firm supplying consistently high-quality products may have its image undermined by another firm with lower or more variable quality. The added costs of achieving and promoting a consistently high quality product may, then, not be rewarded by either an increase in sales or a premium price.

6) The recurring problem which plagues the agricultural industry of price instability induced by fluctuations in supply will also have detrimental effects on fish farmers. This instability, caused by the time it takes farmers to alter production levels in response to changing price signals, leads to overproduction in some periods followed by distress selling and bankruptcies. It results from individual farmers not accurately forecasting the impact of their *collective* production increase in one period on prices in a later period.

This problem already haunts analysts observing the European salmon farming industry. According to one publication, "... by 1990 production capability will double projected demand, if we continue as we are."[15] and another, "Production of farmed Norwegian salmon continues to increase, however, and some people think there may be a collapse in the market..."[16]

7) For many species, Canadians lag behind other countries in aquacultural experimentation and development. Even though a market potential may exist for a farmed product, it may not be possible for the Canadian industry to be competitive with foreign suppliers. The large production increases anticipated for European salmon farms may, for example, decrease prices to a level where an emerging Canadian industry cannot be competitive.

The potential problems faced by the industry can be illustrated by examining development of an industry supplying pan-sized salmon in British Columbia. Stimulated by research and technical advice provided by the Pacific Biological Station in Nanaimo, along with government subsidization, salmon farmers began to raise pan-sized coho salmon for market in the mid-1970s.

The rationale for producing a pan-sized product was twofold. First, over one-half million pounds of trout was being imported into British Columbia, primarily from Japan. Producers felt that the pan-sized salmon was a superior product compared to the imported trout and would displace this product. Second, the pan-sized product, being an immature fish, would be ready for market much more quickly than if producers waited for the fish to grow to maturity. As such, producers would receive a return on their investment much more quickly which appears to have been critical because of the low level of capitalization of the original firms.

Total consumption of pan-sized coho salmon in British Columbia has risen from less than 1 000 lb in 1975 to over 800 000 lb in 1982. In addition, B.C. producers export approximately 160 000 lb of this product, primarily to the United States. Trout imports, on the other hand, have declined since the initiation of the pan-sized industry, with a sharp decline in 1982. The source of imports, however, has changed markedly in recent years. Up to 1979, Japan supplied the bulk of imported trout while the United States has been the principal supplier since that time.

These figures paint a bright picture for the development of the pan-sized salmon industry. The actual story is not so positive. Prices for pan-sized coho rose steadily until 1980, reaching a high of $5.68 per piece in that year. A small price decline in 1981 was followed by a collapse to $3.55 per piece in 1982. The reason for the collapse was that the largest producer went bankrupt flooding the market with fish to liquidate its operation. The sudden surge in sales in 1982 actually reflected a collapse of the industry.

What went wrong? The factors leading to the severe 1982 reversal in the industry are numerous. Fresh trout and pan-sized salmon imported from the U.S. provided much stiffer competition for the B.C. product than had the frozen Japanese import. The fact that the product was fresh and available year-round made it attractive to both retailers and restauranteurs. Also, the price of the imported salmon and trout was less than that of the domestically produced pan-sized salmon.

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[12] Kirby (1982), p. 160.

[13] *Fish Farmer*, Vol. 5, No. 7, Sept. 1982, p. 36–37.

[14] *Seafood Business Report*, Vol. 81, No. 1, Winter 1982, p. 41.

[15] *Fish Farmer*, Vol. 5, No. 4, March 1982, p. 6.

[16] *Aquaculture Magazine*, Vol. 8, No. 4, May/June, 1982, p. 34.

The higher-price B.C. product was only available on a seasonal basis due to the seasonal availability of eggs. Inadequate distribution channels for the domestic product increased the irregularity of product availability. The perilous financial condition of some producers forced them to sell a portion of their available supply simply to stay afloat. These supply uncertainties hindered attempts to convince retailers and restauranteurs to carry salmon rather than trout.

Little advertising or other promotional activity was carried out by the industry as member firms could not agree to undertake generic advertising. Thus any quality differences between B.C. pan-sized salmon and U.S. trout were not reinforced in the minds of the consumer. The similarity of taste between the two products and the fact that the salmon turned white upon cooking diminished the superiority of the salmon over trout.

Perhaps the fundamental reason explaining the inability of the industry to cooperate in promoting the product was the lack of quality standards for firms in the industry. Quality levels varied widely between firms eliminating the precondition for pursuing generic advertising — production of a product of consistent quality.

STRUCTURAL IMPERATIVES

The above discussion in the section "Response of the Conventional Fishery" showed that the conventional fishing industry has not yet responded fully to the changing demands of the market place. The aquaculture industry, on the other hand, is not burdened with many of the structural deficiencies of the conventional industry and has, therefore, a much greater opportunity to respond in a positive and profitable way to changing consumer preferences. Such a response, however, hinges crucially on the industry's ability to resolve the problems facing it as outlined above.

Perhaps the key area where the industry must focus is to capitalize on its superior ability to meet the changing specifications of the market place. Fish farmers can control the timing, size, quality, and physical characteristics of their product in such a way as to maximize the profitability of raising fish. Profits earned will not be squandered on unproductive investments in harvesting and processing capacity, as has been the case in the conventional fishing industry, but can be reinvested in cost-reducing technology and promotional activities. But success is contingent upon a number of crucial factors, which if not adequately addressed will limit the growth potential of the industry.

It appears that the various growth inhibiting factors facing the industry all have one potential solution — that is, a strong, coordinated industry organization. Such an organization could benefit the growth of each participant in the industry as follows:

1) Successful marketing of aquaculture products dictates extensive research into consumer tastes and consumption patterns as well as into the role of domestic aquaculture relative to the conventional fishery and foreign aquaculture operations. Future demand conditions must be accurately assessed. Just as importantly, however, future supplies and prices from foreign sources must be anticipated. Knowledge of those factors may restrain a firm from entering a particular product line *even if present demand and supply conditions indicate it would be profitable to do so*. Knowledge of the availability of cheap trout from the USA would have altered the production strategy of B.C. salmon farmers. Likewise, predictions that supplies of farmed salmon from Europe will more than triple over the next 5 years should be considered before Canadians invest heavily in farmed salmon. Such an increase in supply could depress prices well below current levels.

The research necessary to accurately predict future demand and supply conditions would be too costly for a single small firm but could be undertaken through an organization representing all the firms in the industry.

2) A significant market penetration by aquaculture products must be supported by an extensive advertising and promotion campaign. The lack of consumer knowledge about seafoods must be dealt with along with the poor quality image associated with seafood products from the conventional fishery. The objective of advertising efforts must be to illustrate the superiority of seafood as a source of protein and differentiate farmed products from that of the wild fishery. The payoff from such advertising would accrue to the industry as a whole rather than to an individual firm, which may not be able to afford such an investment on its own in any case. Such advertising could best be undertaken by an organization representing all firms producing a given product.

Countries which have been making significant and successful moves into fish farming all have central organizations which fund advertising. In Norway, where the Raw Fish Law requires a nonprofit, cooperative marketing board for fish farmers, a 1% levy is paid by both the buyer and seller to support the co-op. This levy is reported to have raised about £ 825 000 to support the marketing of Norwegian farmed trout and salmon in 1982. In Scotland, the Scottish Salmon Grower's Association has enlisted the support of 95% of industry members to fund marketing efforts. This Association launched a £ 50 000 advertising campaign in 1982.

While generic advertising is a relatively new concept in the seafood industry, other industries are already well advanced in this activity. For example, the Kirby Report points out that the dairy industry budgeted $27.9 million in 1982–83 for generic promotion, raising the necessary funds through a producer levy.

3) For generic advertising to be successful it is mandatory that product quality from each fish farm be consistent. Thus, an organization charged with promoting the sale of the product could also devise and implement quality control standards. This strategy has been followed by the Scottish Salmon Producers Association: "... the next few months will see us able to begin to use the(se) agreed upon standards as part of a special association backed logo."[17] The production of a product with a guaranteed quality level is a major source of differentiation between armed and wild products.

4) Effective distribution channels must be developed which ensure products get to the right place at the right time. Since a major part of the strategy of the aquaculture industry

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[17] *Fish Farmer*, Vol. 5, No. 4, March 1982, p. 10.

must be to supply fresh, high-quality fish year-round, good distribution channels are critical to the marketing success of the industry. The least cost method of achieving this would be to attract food distributors with established connections. To convince these middlemen of the desirability of distributing fish products will require a coordinated strategy by the industry to both educate the brokers on seafoods and guarantee consistent supply, price, and quality levels.

5) The tendency for both supplies and prices of aquaculture products to be unstable is perhaps the most serious long-term problem faced by the industry. In agriculture this phenomenon has contributed to the formation of marketing boards and the allocation of fixed quotas to farmers. While any method used to control supply will be contentious, some way to stabilize production will be required to prevent a boom and bust industry characterized by periods of high profits followed by periods of distress selling. An organization of fish farmers is one vehicle for controlling supply.

6) A final advantage to organization is the added bargaining power it would impart to industry participants relative to buyers of the products. Increased bargaining power is especially important where buyer concentration is high, such as the United States. More bargaining power quite simply means that fish farmers get a higher proportion of the final price paid by the consumer for their product.

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THE HUMAN SIDE OF AQUACULTURE

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ABSTRACT

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When aquaculture appears on the list of projects to foster rural economic development it is there because it promises to provide employment and increased revenue for an economically disadvantaged area. Aquaculture can fit as well into situations where socioeconomic levels are high; where it simply contributes to business and technological development. However, for the purpose of this paper, the socioeconomic dimensions of aquaculture will be limited to its role in economically disadvantaged settings.

Within this limitation it is possible to identify a range of goals for aquaculture. If one of those goals is human enhancement, it, like the goals of stabilizing employment or increasing family income, must be firmly established from the beginning. It will affect every aspect of the aquaculture project. Emphasis on human development affects the way technical information is provided, it affects the locus of decision making, the speed at which a project progresses and, in the early stages at least, it is bound to cause financial inefficiency.

This paper attends to some of the imperatives associated with developing human resources in the process of establishing an aquaculture project. The imperatives include the need to be precise about the purpose of the project; to be precise about which individuals and groups will be involved in the project; to be precise about their respective learning needs (i.e., who will be required to change which behaviors?); and the need to have technical competency to bring about the adoption of new knowledge and skill.

The paper makes connections between these proposed imperatives and the experience of representatives from several aquaculture projects in the Maritimes. It attends to the gap between the ideal and the reality, and presents suggestions of ways to bridge the space. A key suggestion is to approach aquaculture with the best practices of agriculture extension. It is also suggested that adult education is the avenue to socioeconomic development within the aquaculture industry.

INTRODUCTION

The human factor in the enterprise of aquaculture runs the gamut from policy setting at the political level, through scientific experimentation in biology and engineering at the institutional level, to growing practices and marketing activities at the field level. Despite its many facets, aquaculture is essentially a business venture. It will be fostered in relation to its potential to create wealth and will only develop if it succeeds in producing wealth. Although they are sometimes used as a way to realize rural economic development, very few aquaculture projects are launched solely for the social benefits they bring through employment creation. Whether they be located in the midst of poverty or prosperity, in the long run aquaculture ventures must produce wealth.

This paper attends to the human development side of aquaculture. It's principal purpose is to stress the importance of taking advantage of learning opportunities for persons who work in the farming end of the aquacultural process. Such learning opportunities are found in virtually every stage of growing and harvesting. Provided human development is an objective of aquaculture, the potential educational value for the "pondside practitioner" is substantial. There are also inevitable educational benefits of aquaculture for such professionally trained personnel as biologists, chemists, engineers, and market analysts, but the main focus of this paper is on the new, nonprofessional fish farmer. It is also limited to the role of aquaculture in economically disadvantaged settings and does not discriminate between projects which emphasize social welfare outcomes and those which are strongly profit-oriented.

The paper makes no distinction between enterprises run by large corporations, government, private individuals, local coöperatives, or any other organizational arrangement. It stays with the notion of opportunity for the development of people who work and learn in a technically strong and financially healthy industry. It stresses the importance of having aquaculture pay attention to human development and suggests ways to do so.

The observations and suggestions presented here are not rooted in imperical data. They are the product of my own experience as a lifelong rural resident and as a professional adult educator.

AQUACULTURE AS A DEVELOPMENT PRIORITY

Aquaculture occupies a relatively minor place in the overall Canadian fishery context. It has probably gained more attention as a result of well-publicized international projects than it has through our own public expenditure. It is seldom mentioned in Canadian economic development literature. A survey of the Canadian Council for Rural Development's annual reviews for 5 years prior to the Council's demise, reveals only one brief mention when it refers to aquaculture as a way to supplement rural income. Nor do the reviews of the Economic Council of Canada refer to aquaculture as a serious way to create wealth through the production of food. As long as aquaculture remains a minor sideline in the realm of rural economic development, few advances are possible in the current level of research and practice. Until society places a much higher priority on aquaculture, we are left to tinker with the prospects, without funding to turn them into reality.

It is very difficult to catch the attention of low-income people when we are promoting development which is not highly valued by society. They cannot be expected to take the development prospect seriously when they have no evidence that our governments do. It is not surprising when they treat aquaculture as another of government's make-work projects to be replaced within a few years by a make-work effort of another kind. An important outcome of this Conference would be a plan for establishing the development of aquaculture as a major, national goal. With such status, it will be accorded the research and development attention it deserves. But policy makers will first have to be convinced about aquaculture's splendid potential as a source of food and wealth. If this Conference achieves nothing else it will be immensely important as a vehicle for marshalling facts and figures to help policymakers determine the future of aquaculture in Canada.

GOALS OF AQUACULTURE

Two goals of aquaculture are to produce wealth through food production and to improve social conditions in economically disadvantaged communities. These are potentially conflicting goals. Without very special support mechanisms, the community requiring the part-time injection of economic activity which aquaculture promises, is not well prepared to handle a successful food production enterprise. When both goals are included in a single project, care must be taken to foster development of knowledge and skill; care must be taken to sort out the relative importance of each goal; and care must be taken to acknowledge that an accounting of the cost of the social development goal should be distinguished from the cost of the food production purpose. Presumably, both goals are worth achieving and it is therefore important to ensure that the cost of each is accurately acknowledged. One cannot blame the inadequacy of aquaculture if low productivity is the result of poorly trained personnel.

The Salmonid Enhancement Project (SEP) set out to achieve both goals in 1977 when it established, in addition to objectives relating to salmonid enhancement, a Community Economic Development Program with some of its objectives directed toward human resource development. The 1982 assessment of that program by Dennis Rank reports success in terms of employment goals while raising doubt about the program's ability to increase the commitment of local people to many of the essential features of aquaculture:

> "I would recommend that decisions related to biotechnical affairs be left strictly up to the relevant DFO authorities for now. It is clear from my discussions with the various CEDP Band leaders and other interested Natives that very few are aware of the complexities of salmonid enhancement, harvesting, and marketing." (Rank 1982, p. 101)

The SEP is a remarkable example of a program designed to achieve both social and industrial goals. It explicitly outlines objectives relating to each, for example, two of them are:

1) To foster development of economically disadvantaged communities or regions. (Note: In Rank's report an elaboration of this objective is "improving self-reliance, independence, and social and economic stability of Native peoples of B.C.")

2) To preserve, rehabilitate and/or enhance salmonid habitats.[1]

Materials describing the CEDP include a detailed outline of a training program "to enable project employees to obtain as much training and education in salmonid enhancement as they desire (or are able) to learn."[2] The training program was described as relating closely to the project, open to all project employees regardless of academic background and previous training, and providing a successful learning experience for every student. Unfortunately, I did not have the opportunity to pay close attention to the outcomes of the CEDP effort. A 1981 description of the project summarized that "relatively small-scale, people-oriented enhancement facilities are economically efficient in the production of fish in addition to providing significant social benefits."[3] My earlier reference to Rank's 1982 assessment suggests that it would require more than had been done up to that time if nonprofessionals were to be sufficiently competent to handle biotechnical aspects. An interesting question in terms of the dual goals of wealth generation and of human development is to determine precisely the requirements for achieving both, including the training competency required to limit the risk of financial failure.

SYNCHRONIZING AQUACULTURE GOALS

The obvious hazard of working toward human development through aquaculture is that the growth cycle of the fish doesn't accommodate the rate of the fish farmer's skill development. It takes extraordinary planning and training capability to spell out the critical linkage between the requirements of the business and educational goals — so extraordinary that the usual practice is to soon abandon one in favor of the other. If project designers are sufficiently committed to human development they will know the precise requirements which must be met; they will designate alternative resources which must be employed to minimize chances of business failure until such time as all of the project's requirements can be met by local resources. It is a delicate balancing act requiring close collaboration of project initiators and complete understanding of the venture on the part of the sponsoring agency. These are formidable requirements and extend well beyond the realm of fish farming technology into sophisticated approaches to teaching and learning.

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[1] From unpublished report of the Community Economic Development Program (CEDP), Annex II, "Description of Community Economic Development Program and Summary of Social and Economic Benefits," Draft, February 3, 1981, p. 1.

[2] Appendix II — 4, Description of the CEDP Training Program, p. 1 (unpublished report of CEDP).

[3] *Ibid.*, p. 9.

The job of developing knowledge and skill among newcomers to aquaculture must be done as an incremental process. It calls for meshing various related skills and careful timing. It means sequencing learning experiences, for phasing in another skill as a more basic one is mastered. And throughout there must be reliable evaluation of trainee performance. The risk is total failure of the business project.

These training dimensions are not unusual. They are part of the professional approach of any successful curriculum designer, instructor, and evaluator. They assume difficult and critical proportions when considered in concert with the demand to meet fish production goals and to employ previously unskilled personnel in the process. Clearly, any successful aquaculture project which places value on human development will have ongoing interaction between the fish farming technologists and the human developers.

ADULT EDUCATORS THROUGH AQUACULTURE

The future, inevitable development of a viable aquaculture industry in Canada will bring with it an eventual designation of skills required to perform a range of acquaculture-related jobs. It is time to begin describing those skills in such a way as to catch the attention of educational institutions. Thus far I have referred only to the educational function of the aquaculture project for the new, unskilled fish farmer. This is field-level training requiring professional instructors. What are the skill requirements for those instructors? Are they, ideally, aquacultural technologists who have curriculum planning instructional and performance evaluation skills? Or, are they educators first, who have an understanding of technical aspects? Or, is the aquaculture project with a goal of human development staffed by both types of professionals working in close collaboration? It is time to spell out the kinds of competencies required to achieve both aquacultural goals if we are to have professionals function in a way that allows the aquaculture project to permit learning to be organized for pondside workers around the technical constraints of the project.

The systematic process of adult education programming in the context of practical, highly-technical situations such as aquaculture, is one for which we have many qualified personnel in Canada. They are located principally in community colleges. They are able to program for variations in individual differences in levels of knowledge and skill; they are able to prepare individualized learning materials for use in diverse field and classroom settings; they are able to treat adults as autonomous learners; and they are able to measure change in individual performance in relation to the performance requirements of the project. These are not extraordinary capabilities; they are the stock-in-trade of adult educators and they are there for aquaculture to use in the achievement of the human resource goal. Just as we have learned to consult an engineer for expertise related to the engineering aspect of our projects, we are now going to have to learn to consult adult educators for expertise relating to the human development aspect. My impression is that physical technologists (e.g., chemists, physicists, biologists, engineers) are not yet sufficiently aware that the human development side calls for particular systematic attention. It was a physical scientist who said the social scientists are in the hardest business of all — trying to understand how humanity works (Lewis 1981). If, as the list of participants in this Conference suggests, aquaculture is heavily weighted in the direction of physical scientists, it will take deliberate attention to ensure that the human development aspect of the enterprise is also assisted by competent professional resources.

AN ORGANIZATIONAL BASE FOR LEARNING IN AQUACULTURE

At least three groupings of personnel will be key to the development of aquaculture as an important industry in Canada. One group includes institutionally based subject specialists who are in the laboratories of the universities and research stations. Their fields are diverse and include medicine, engineering, business, biology, agriculture.... They teach in technical schools, community colleges, industries, universities.... A second group includes field practitioners whose backgrounds of expertise cover a range of aquaculture-related subject specialities and the ability to perform as educational technologists. A third group, and the one that forms the principal subject of this paper, comprises local, nonprofessional project employees: the persons whose development forms one of the two purposes of the aquaculture project. The educational development of each of these groups is important for the industry. Surprisingly, without commitment from each of the two professional groups there will be little hope for achieving the human development goal at the community level. Only an interactive enterprise will ensure achievement of that goal and the challenge for aquaculture is to find an organizational base that will permit exchange between the three groupings.

Within the two professional groups (subject area specialists and field practitioners) there are sufficient opportunities to exchange knowledge and develop skills through such media as journals, professional organizations and conferences. These are normal routes for continuing professional development. The organizational personnel is not as straightforward.

The dimensions around which local people might be engaged in learning through aquacultural projects include a wide range of possibilities. For example, they will vary according to the initiator of the project. Was the project parachuted into the community for political reasons to be run by a local entrepreneur? Or, is it the product of long-term initiative taken by an individual or a group of citizens following careful study and decision-making about alternative possibilities? Is it one of numerous economic development projects introduced by a crown corporation to change the pattern of employment of a region? Response to questions about who initiated and who owns the project will determine the kind of organization required to sustain it. If it develops through a spirit of mistrust, it will require quite a different approach than if it were initiated out of high community commitment.

Thus, a worker-owned cooperative structure implies that the worker might have far greater commitment to the success of the enterprise (and hence to his own learning) than would the worker who is employed in a privately or publicly owned enterprise. There is a very wide range of organizational possibilities for learning within the third group.

But if interchange between the three groupings is the principal factor for enhancing both industrial and human resource development, then a key concern is to establish an organizational structure which will permit exchange between the groups. My purpose is not so much to propose the ideal structure as to emphasize the need for exchange. Whatever the structure it must give the educational technologist the capability to tie specialized subject area resources to the learner when and as required by the learner. And, just as important, it must leave the field practitioner in a position to convey the requirements of the local learner to the subject specialist. Sometimes that will be in the form of demand for research.

One excellent model and, in my view, one to which we pay insufficient attention in Canada, is the United States Land Grant System of Cooperative Extension Services. It permits free exchange of knowledge and of questions between research personnel and field practitioners. It requires cooperative funding between federal and state (provincial) levels of government. Those funds are granted to designated institutions, each having a state-wide (in the case of the USA) mandate. We have many reasons to doubt the transferability of this model to the Canadian context. But at least within the limited area of aquaculture we might endeavor to achieve that type of arrangement which provides for a smooth flow of knowledge and skill development assistance from the subject specialists in the field and back from the field to the agencies. The go-betweens in this exchange system are the educational technologists or, if you prefer, aquacultural extension agents.

The current, low level of aquacultural development in Canada raises a question about the practicality of the idea of an extension service in aquaculture. Surely the validity of that question is temporary. Growth of the industry will make it so. Meanwhile, existing agencies can provide localized extension service. The important point is not to lose sight of the fact that there must be open exchange between the three principal groups involved in the enterprise. And when human resource development is a goal of aquaculture, an educational function involving all three groups is imperative.

I suggest that our respective university extension services are in an optimal position to take on the educational function. Regardless of which agency handles the task, the technologies associated with aquaculture must be coordinated at the community level through competent educational technologists. They, in turn, are to ensure that the aquaculture project meets the goals of economic viability and of being an instrument for human development.

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AQUACULTURE — "A MONETARY BLACK HOLE?" (ECONOMIC PERSPECTIVES IN DEVELOPING AN AQUACULTURE INDUSTRY)

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ABSTRACT

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Aquaculture in Canada must be looked at both from the macroeconomic, as well as the microeconomic point of view, to attempt to put the economics of the industry in perspective. A simple or even complex economic model developed to test the economic viability of the culture of a particular species, has little long-run consequence or validity because of the volatility of pricing and supply in the markets, the site-specific biological factors, economies of scale, innovations, and the "hot and cold" attitudes of governments providing short-term support of long-term requirements.

The macroeconomics of aquaculture have to be considered. Consideration has to be given to the replacement of imports using nonproductive unemployment insurance commission payments, or welfare payments. The economic viability of aquaculture has to be considered from a comparable base. We must strip the hidden subsidies that exist in the fisheries and cereal grain production, that flow through to the other animal protein production, before assessing the long-run viability of aquaculture species compared to other foodstuffs. We must compare our true economic costs to those of other source countries.

It is difficult to attract investment into the industry because of the high-risk to low-leveraged growth characteristics in aquaculture, compared to other developing advanced technology industries. Government assistance programs are generally not suited to aquaculture, because the major requirements of the aquaculturist relate primarily to working capital "inside the farm gate," whereas the existing programs relate primarily to capital loans.

Government incentive programs, such as research and development tax incentives, accelerated depreciation, small business deductions, etc., although available, generally do not directly address the difficulties in aquaculture. Aquaculture is a "different breed of cat," and needs its own programs.

A rigorously developed long-run strategy has to be evolved for each candidate species. To accomplish this, extensive cooperation must be developed among industry, governments, and research institutions. Adequate programs will have to be instituted to fund the planning, research, and commercialization. The bridge to be crossed is too long and expensive for an individual entrepreneur, and left to government and consultants alone the Aquaculture Monetary Black Hole will continue to consume taxpayers' dollars with little results.

However, if properly approached, success will result. An industry employing thousands and contributing to the Gross National Product in excess of the wild fisheries, will develop — at least on the West Coast.

PREFACE

The background that forms the resource base for this paper consists of extensive personal analysis of shellfish culture and commercialization, some analysis of pen-raised salmon commercialization, and a very small amount of analysis of trout and catfish pond culture. The comments and opinions reflect personal endeavours, past and present, to create two commercial shellfish culture operations, the operation of a restaurant, and the operation of a specialty seafood processing facility, with domestic and international sales.

In addition, my background includes considerable exposure to and involvement with other industries, such as mining, construction, and, more recently, high technology industries. My comments reflect primarily my West Coast experience, which may differ from others. Further, I do not pretend that the contents of this discussion paper reflect an intensive review of the literature available. Many studies and reports have been produced on the subject. Indeed, if the time and money spent on reports and studies had been directed towards commercialization, the industry would probably be alive and well today. Instead, we have a record going back 15 years, identifying the status of the industry, specifically the problems and how to set up the infrastructure, but very little has been done to find the solutions to the identified problems.

Neither the status of the industry nor the problems have changed, but here we are again identifying the status and the problems. Let us hope that this Conference leads to the solving of problems, not just identification of them.

INTRODUCTION

When the fields of endeavour that fall under the term "Aquaculture" are explored, it is found that projects are so diverse that any form of generalization has exceptions, and thus to cover such a broad field as economic perspectives in a short discussion paper is extremely risky. However, in an attempt to grasp the Canadian perspective, the term "Aquaculture" in this paper will speak generally to those systems that are open circuit primarily using natural resources, (such as pullution-free streams, ponds, and oceans), in a more intensive way than Mother Nature. This eliminates closed curcuit intensive systems that have high capital requirements, and are not being widely considered in Canada. Further, hot water effluent systems seem to be too specialized to fall within consideration of this discussion.

The primary thrust of this paper will be consideration of some of the main components of the question of economic viability in Aquaculture. Economic perspectives in the areas of microeconomics, macroeconomics (in which social welfare ecomonics will be included), funding through private investment potential and government incentive programs, and markets, will be reviewed.

Finally, comments will be made on why progress in Aquaculture is slow, and how an economic strategy would encourage development.

AQUACULTURE MICROECONOMICS

The components of microeconomic analysis for Aquaculture are the standard elements — direct costs, variable costs, fixed costs, indirect costs, and revenues that are used to conduct analyses to assess the optimization in the use of resources and production of the desired product. Models that are developed can be extremely complex or relatively simple. The I.D.R.C. publication 193e (1) outlines a range of analysis that extends from complex modeling of existing production systems that would be useful to policy-makers (but not necessarily for a specific site), to simple on-site models of experimental production systems, a review of which will eliminate the necessity to elaborate further in this paper. Some models have also been prepared for specific species in Canada. Examples of these are Fralick's oyster study (2) and pen-raised salmon study (3), and Anderson & Associates' Atlantic salmon study (4). These models, whether based upon actual operations or experimental information, have both their benefits and negative factors. On the positive side, they give some indication of the feasibility of the project, they identify high cost areas that should have further research, and indicate the direct cost-revenue relationship to test sensitivity of economies of scale.

However, it must be recognized that the numbers used in these models are often averages or estimates because of a lack of information, and, consequently, the models are only as good as the information available. Further, they represent a static situation. Using the models as presented to test the long-run economic viability of a particular species has little validity, because of the volatility of prices and supply in the market, site specific biological factors, economies of scale, innovations, and, finally, hot and cold support by way of subsidies or support programs from outside agencies.

Fluctuation in any of the above could change a "go" decision to a "no go" investment decision. Individuals who have produced the various studies recognize this aspect, for example, in Fralick's oyster study (2) p. 47, he states "The estimated costs to produce oysters by the various techniques have been presented as absolute numbers, but when the wide range of management styles and firm types is considered, it is obvious that these values could actually be expressed as a broad range."

Let us look at a few examples of these ranges. Let us first consider price fluctuations. At the time of Fralick's oyster study (2), the posted marketing board price was between $13.50 and $16.32 per U.S. gallon of meat, whereas actual sale prices for two of the larger producers were 40 to 50% higher. The model farm producing 10 000 gal. had a net income of $13,103, on a required cash base of approximately $150,000 for a marginal investment opportunity. However, if a farm averages a 40% higher price, the farm net income would have been in excess of $60,000, making it a very attractive investment opportunity. A similar example exists in pen-raised salmon: whereas one group was selling for in excess of $6.00/kg another was less than $4.00/kg.

An example of an innovation that would change the feasibility of oysters is the introduction of an artificial cultch in off-bottom culture. One system being tried now will reduce the cost of shell-stock production from $5.35/U.S. gal. to under $2.00/U.S. gal. making a production cost reduction of 66%.

Generally speaking, the microeconomics models developed for Canada must be considered feasibility studies only. The models to date have indicated that reasonable economic returns can exist, and the next step in any normal economic strategy would be to develop commercial scale pilot operations.

The only truly valid microeconomic model to address economic viability would be a fully funded, fully supported pilot project where actual costing of work components and marketing studies could be undertaken. This means a well-planned operation done by industry but supported by government, biologists, economists, and accountants.

AQUACULTURE MACROECONOMICS

A basic premise of economic theory is that economic agents act in a manner which maximizes their welfare. Unfortunately, if free markets fail to allocate resources in such a way to maximize the well-being of the society as a whole, intervention by government may be justified. This may occur if private welfare objectives are not sufficient in themselves, or goal consistent in order to achieve the maximum social welfare.

If Aquaculture is profitable, presumably it will be taken up without government intervention. If it is not profitable it is not worth pursuing anyway, and should not be encouraged unless there are net benefits for the society as a whole, not captured by the individual producer. Such a discrepancy between social and private benefits and costs may arise from a failure of the market to register the true society value, either because of the good itself or the imperfection of the market.

In the Aquaculture industry, government intervention may be warranted in the case of market failures, or in the case of income redistribution.

In considering market failures, although many specific examples could be cited, only two will be reviewed here. The first, market failure that occurs because of the infant nature of the Aquaculture industry, and the second, that of lack of infrastructure.

The infant nature of the industry introduces considerable risk and uncertainty. Concerns about environmental suitability, disease, technological innovations, or price supply relationships, all lead to a great deal of difficulty in endeavouring to obtain credit, investment, and long-term marketing stability; components that are essential for development of the industry. Government support may be required to get the industry beyond this infant stage.

The second market failure, that of lack of infrastructure requires an individual farmer to break new gound in every endeavour, whether it is obtaining permits, setting up marketing and distribution systems, new types of packaging, or research and development. All of these result in an inordinate load for the individual grower, and, without assistance, often results in lack of entry or failure of the enterprise. Government support to provide infrastructure would overcome this market failure.

Another area of possible government intervention is in income redistribution. As Canada creeps towards a guaranteed annual income, the decision to produce or not to produce domestic product becomes a more complex decision. For example, should we pay an individual in a coastal community (through Unemployment Insurance, Welfare, or guaranteed annual income), to produce nothing, or do we pay the individual these funds to subsidize oyster production. The latter would result in domestic product instead of importing oysters, and thus would assist in the balance of payments. Assuming the the individual has no alternate possibility of employment, the production of oysters would be attempting to optimize social welfare.

It might be interesting to point out that in Scott and Neher (5) on p. 26, the total Canadian fishery in 1978 had a net private economic contribution of zero, and that if one adds the cost of regulation, the net economic benefit for the fishery is minus $325 million, and this does not even include an internal rate of return on Fisheries and Oceans assets, which would make the negative contribution much higher.

Further, it does not reflect other indirect subsidies, such as accelerated capital cost allowances, Fishery Improvement Loans, and tax exemptions throughout the industry.

Therefore, when considering the economic viability of Aquaculture, and comparing the potential to other food production systems, comparisons must be made on a fair basis by stripping hidden subsidies that exist in other systems. Macroeconomics and social welfare economics must be considered in addition to the microeconomics of Aquaculture.

INVESTMENT POTENTIAL

Large companies have been investors in the Canadian Aquaculture industry, (Union Carbide in Apex Bio-Resources Limited, Marine International Corporation in Seapool Fisheries, B.C. Packers in the oyster industry in British Columbia), but they do not seem to be around today. Many individuals have entered the industry and many have left, usually leaving their savings behind. A few are still around, but when you look at their operations, they are often subsidized through Research & Development contracts, supplemented by outside income, or they are a synergistic operation with a processing plant in other production systems.

This reflection on past or existing investors leads us to the necessity of looking at the investment perception of the industry. When the industry is assessed for risk and uncertainty, many concerns arise such as supply fluctuations, price volatility, competitive foodstuffs in the marketplace, diseases, weather, and technological discoveries. Often the conclusion is that although the individual risks or uncertainties have a low probability, there exists a broad range of exposure.

When the industry is assessed for potential return on investment from existing microeconomic models, the returns range from 10% to 20% — about the same as bank interest has been over the last 2 years.

When a species market size in considered, the markets appear small with a domestic market in the $2–$10 million range, and export markets in the $10–$100 million range, as compared to hundreds of billions of dollars in microelectronics, biotechnology, and resource based industries.

Views of the oyster industry are that it is still decreasing in production and it is not economically viable. This is particularly important in light of the fact that it is considered an industry with a high probability of success.

In summary:

1) Large companies have tried and failed.
2) Individuals have tried and failed.
3) Few operations survive, and they are usually supported by other activity.
4) The industry has a wide range of risks and uncertainty.
5) The projected return on investment is about the same as bank interest.
6) The market size is small compared to microelectronics, resource industries, and biotechnology industries.
7) The oyster industry is shrinking.

This does not present an attractive investment picture. However, each of these apparently negative scenarios must be explored in greater depth.

The large organizations who have attempted Mariculture did so with adequate capital but with too much haste. That is, they either tried to accomplish too broad a range of activities without the proper research, or they went too large without going through a pilot project phase in which the costs, markets, and production systems were proven out.

The individuals who have entered and left, often were undercapitalized even for a "Ma and Pa" operation. Further, they were often ill-prepared both in biology and (more importantly) in business, as they were usually transplants from government and academia, or had little — if any — business experience.

These people soon find that an immense amount of labour is required to raise food in the ocean. However, with mechanization the backbreaking labour disappears, but you are no longer considering a cottage industry but one better suited to smaller companies. Companies within the $500,000 to $2 million range will likely be of a size to optimize on mechanization, and achieve all economies of scale.

The synergistic aspect of the surviving firms leads us to a positive positon rather than a negative one. In the type of coastal farming envisioned, we see that harvests may be seasonal, thus developing the opportunity of processing minor fishery species which could not otherwise be developed. In addition, alternate fisheries provide product during start-up phases, and thus help generate revenue over the lean development years.

Risks and uncertainties do exist, but as a species industry develops past its infancy, many of the risks disappear. Both the trout and catfish industries in the U.S. went through supply pricing cycles, but have settled down now. Research through the pilot project stage solves many of the biological problems. Concern about technological innovation in our fledgling industry should only be perceived as beneficial, as we can participate in new generations of culture methods but, because of the infancy of the industry, we are not stuck with old traditions.

The return on investment projected in the microeconomic models reflects only the projected averages. As pointed out earlier, the oyster and salmon price in the Fralick models was low compared to actual prices being received by some farmers. The higher prices could reflect very respectable returns, on investement of 40 to 60%.

As far as market size is concerned, compared to microelectronics or biotechnology, one should also consider the number of competitors.

A billion dollar market with 1 000 competitors may be less attractive than a $10 million industry with only five competitors. Also, we should note that not all countries have the existing infrastructure and extensive pollution-free waters that gives Canada a definite advantage.

And, finally, why is the oyster industry shrinking? My speculation would be that we are just witnessing the depletion of wild stocks the industry has not advanced to a culture operation. Therefore, lack of expansion of the industry does not necessarily reflect a lack of economic viability, but rather the infant nature of the culturing stage in the industry.

In summary, investment potential appears bleak and unattractive, but reflects only the fledgling nature of the industry. However, even though the concerns in most cases can be alleviated, it must be recognized that investors often will not proceed past first impressions. In order to get investment into the industry, considerable incentives must be offered, or the industry must be aided past the infancy stage.

GOVERNMENT FINANCIAL ASSISTANCE PROGRAMS

During a past government industry policy development seminar on Aquaculture held in 1973 **(6)** the topic of Financial Instruments was reviewed with the following summary report:

"The fourth major topic was discussed in a special plenary session. It posed the question concerning the need for new instruments to absorb financial risks in aquaculture ventures.

The various incentive and development programs available to Canadian industry through the Department of Industry, Trade & Commerce, was reviewed. Mention was also made of the National Research Council programs, Department of Regional Economic Expansion programs in designated areas, Provincial Loan Bonds, the Industrial Development Bank, and programs for pollution control and industrial development operated by Environment Canada.

It was considered that a major limitation to the development of viable aquaculture companies is a shortage of capital and operating funds. Many present aquaculture companies in Canada are small-scale operations which exist in isolation from larger corporate sources of funding. They frequently operate on personally guaranteed loan money and lack adequate bankable assets to support large loans.

There was no conclusion made in the discussion that new sources of funding are required, but rather the indication that existing sources of support have not been fully investigated. It is recommended that information on the various present sources of provincial and federal support be coordinated and interpreted more specifically for application to the Aquaculture industry.

It appears that existing support programs are particularly applicable to secondary or ancillary aspects of the Aquaculture industry, particularly with regard to innovative equipment or to such processes as the fishfeed industry."

In summary, they made three points:

1) A major limitation to Aquaculture development is a shortage of capital and operating funds;
2) Information on the various government sources be coordinated and interpreted more specifically for Aquaculture;
3) It appears that existing support programs are applicable to secondary aspects of the Aquaculture industry.

Here we are 10 years later, and the above three points are still pertinent.

Fralick **(2)** p. 64, on the other hand, states after a review of programs that:

> "It is obvious from the descriptions of the programs that funds for both capital equipment and working capital are available to small businesses in British Columbia. However, the *crucial question is whether the grower/processor can fit the working criteria of the review boards who pass judgement on the proposals.* Although financial assistance has been extended to oyster growers in the past, there is some uncertainty about the approval of the present applications given their large number and the uncertainties surrounding the expected supply and market demand for oysters. Quantitative knowledge concerning the domestic and export demand for B.C. oysters is virtually non-existent, yet this information is crucial for coordinated planning of the establishment of culture, processing, and market facilities — the facilities to which loan funds would be applied."

But the key phrase is whether the grower/processor can fit the working criteria. In practice, let us explore some of the existing programs.

Two categories of financial assistance will be reviewed, but it should be pointed out that the review is not meant to cover all programs, but rather just to give samples of what is offered. The first category is "Funding Programs," the second is "Tax Incentives."

Funding Programs

AQUACULTURE PROGRAMS

B.C. Oyster Seed Development Loan

The oyster seed development loan fund was set up to provide money at a low interest rate and with a repayment schedule to match the ability of the oyster grower to repay the loan.

The funds were provided through the British Columbia Development Corporation (BCDC) and administered by the British Columbia Oyster Marketing Board. The interest was set at one-half of the BCDC prime rate, which was 10.25% per annum (October, 1978). Two hundred and fifty thousand dollars had been made available initially — $150,000 during 1978 and $100,000 during 1979. The loan funds were established as a line of credit with lots of $50,000 each being drawn down as needed. The first six months of a loan was interest free to the Board but not to the individual oyster grower. Presumably this procedure was to accommodate any slack and allow the Board to recover some of the costs of administering the program.

The loans were made available "for the purchase of oyster seed, materials, and capital equipment necessarily incidental for the collection and distribtution of oyster seed." The interest on the capital equipment loans was determined individually by the Board. The total loan for seed in a given year would not exceed the cost to seed one-quarter of the individual lease acreage at 25 cases per acre at $20.00 per case. Also, the total outstanding loans would not be allowed to exceed the estimated cost (as above) to seed 85% of the registered acreage of the grower. To qualify for the loan, the applicant had to be a registered B.C. oyster grower, in good standing, and in possession of a lease or licence issued pursuant to the Land Act for the purpose of cultivating oysters.

This loan program, although having good intentions, fell down in the administration and follow-up to ensure that the funds were spent to encourage seed production.

GENERAL PROGRAMS

Low Interest Loan Assistance (LILA)

The Low Interest Loan Assistance program which came into effect in January, 1978 is administered by the British Columbia Development Corporation (BCDC). The funds may be used to establish new manufacturing or processing facilities outside the lower mainland and south Vancouver Island area. (The program is not specially designed for aquaculturists.) The prime criteria for granting the loans are that the project portray a long-term viability, the maximum cost of the project be less that $2 million, and the pro-forma equity be at least 15% of the assets. The loans range from $30,000 to $250,000 with a term equivalent to the shorter of the asset life, or 25 years.

The first six months of the loan period is interest free, after which the interest is calculated at one-half of the BCDC prime rate of 10.25% (October, 1978). In addition, no principal payments are required during the first 12 months of the loan period.

Up to one-third of the capital requirement of the project is eligible for funding. However, as far as Aquaculturists are concerned, this would only apply to the processing side, and does not go inside the farm gate. Also, with a surplus of processing capability in the fishery, lending agents are reluctant to fund new processing facilities.

Agricultural Credit Act

The provincial government of British Columbia established the Agricultural Credit Act in 1974 to supplement existing credit facilities by providing a guarantee for loans to farm operators, and to stimulate growth of the agricultural industry by reducing the cost of borrowing. The cost is reduced by reimbursing the operator for the interest he paid.

The loans are available through a bank or credit union and interest is charged at the bank rates. However, partial reimbursement of the interest may be obtained upon application to the government at year-end. The maximum interest rate applicable to the guaranteed loans is the prime rate of the chartered banks, plus one percent.

The loans are available for both operating and capital expenditures. The maximum loan limit is determined according to the capability of the firm to service the debt: the repayment schedule depends on the production cycle and arrangements can be made to defer or reduce the principal payments during the initial nonproductive stages of an agricultural venture. Although this program was made available to freshwater fish farmers, (*Vancouver Sun* newspaper, March 11,1978), it is not certain if oyster farmers qualify.

This Act, on the surface, appears to be of great assistance, in that working capital or consolidation of debts is allowed. However, in attempting to get a loan, a great deal of resistance may be encountered. One fish farmer, with persistence and the help of no less than four Cabinet Ministers, eventually got a loan.

It should further be pointed out that the guarantee offered to the banks is couched in such a way that only very secure loans would be considered by the lenders, certainly not risky Aquaculture. As an example, one major bank has only put out approximately $1 million in loans under this program for all of B.C. in the field of Agriculture. This certainly does not represent a program of easy access to Aquaculturists.

Assistance to Small Enterprise Program (ASEP)

The Assistance to Small Enterprise Program provided through the Federal Department of Regionl Economic Expansion and the British Columbia Department of Economic Development, was established in July, 1977 to stimulate manufacturing and processng industries outside the major population areas in British Columbia through interest-free, forgivable loans.

The loans are available to both new and existing enterprises for capital expenditures only. The conditions of the loan agreement require that at equity level of at least 20% be maintained on either the aggregate of the new and existing assets or of the eligible capital costs of the proposed project. The maximum eligible capital cost is $100,000. The loan will normally be completely forgiven two years after the commencement of operations — 50% after one year and the remainder after the second year.

The only security is a promissory demand note. Other lending institutions may treat the ASEP funds as equity due to the nature of this note (ASEP representative, pers. comm.). This program is available for processing activities but is not available for farming.

This type of program is good because of the "near" equity nature of the loan, but has the disadvantage of being tied to capital expenditures.

Small Business Loans Act (SBLA)

The Small Business Loans Act permits loans guaranteed by the federal government to be administered by chartered banks and other designated institutions. The maximum loan limit is $50,000, and a period of up to ten years may be allowed for repayment. These funds must be used for the purchase of new capital equipment or the upgrading of existing facilities. Loans which are applicable to fixed or moveable equipment may be granted for up to 80% of the cash purchase price of such equipment, including the cost to install the equipment. The rate of interest on these loans is the prime rate plus one percent.

Federal Business Development Bank (FBDB)

Financial assistance is available from the Federal Business Development Bank for most types of businesses including Aquaculture. The principal conditions for obtaining a loan are that sufficient equity be provided by the entrepreneur so that he is seen to offer an ongoing commitment to the enterprise. The procured funds may be applied to the acquisition of capital assets or used to increase the working capital. Equity as well as debt financing is available, but equity financing is most commonly used to finance higher risk businesses. A typical situation would be for FBDB to purchase a minority interest in the farm initially and then resell those shares at a later date to the private owners at an agreed price above the intial purchase price.

Loans are normally retired within ten years through monthly payments of the principal and interest. However, alternative terms may be negotiated. The return on equity financing is considerably more costly than the debt and varies with the perceived risk of the project. One recent advantage given to oyster growers by the FBDB is the acceptance of leases as security for loans.

The equity group does not consider that Aquaculture has a high enough return on investment because they are looking for a return in excess of 30%, and current economic models show 10 to 20% return. FBDB, like other banks, favours the purchase of capital assets.

Agricultural and Rural Development Subsidiary Agreement (ARDSA)

The Agricultural and Rural Development Subsidiary Agreement programs are administered by the federal Department of Regional Economic Expansion and Agriculture, Canada, and the British Columbia Ministries of Agriculture and Economic Development. The agreement was signed in 1977. Funding is available to Aquaculturists operating outside the greater Victoria and Vancouver areas. Two programs are of particular interest: the research, planning, training, and market promotion section; and the support services and community development section.

The first of these programs has been designed to identify and establish feasibility studies for projects providing development opportunities; to promote market development; and to aid training.

The second program has been designed to assist support services which are necessary for the economic viability of primary agricultural production, and to encourage the development of secondary processing facilities. Within this program there is considerable scope for projects that may enhance the suitability of an area for agricultural businesses, and for the establishment, modernization or expansion of processing operations.

The levels of assistance are cost shared up to 50% of the asset costs for community service enhancement — the governments pay half the cost and the applicant pays half the cost. For new processing facilities, the governments will pay up to 25% of the capital costs plus $5,000 for each new job created, to a maximum of 50% of the total capital cost. Up to 20% of the total capital cost is paid for modernization and expansion of processing plants.

These programs have been of assistance to the industry as a whole, both in industry-type projects and to some individual operators for capital purchase; however, approval of applications is a long and time-consuming endeavour and working capital loans are not available.

Marketing Assistance

There exists both Federal and Provincial export marketing assistance programs which are very beneficial to the industry. Examples are the Federal Program for Export Market Development and the British Columbia Provincial Market Development Program.

Research Funding

Considerable assistance has been given to the industry by way of research grants, contributions, and/or contracts from agencies such as the B.C. Science Council, N.R.C., Department of Supply & Services, Industrial Development Branch of Fisheries and Oceans, and by Marine Resources Branch of the Province of B.C. The unfortunate part is that the research is on an ad-hoc basis, producing a hodgepodge of results and giving little assistance to commercialization, except in a few cases.

Tax Incentives

Tax incentives such as the investment tax credit, small business deductions, Research & Development write-off's, accelerated capital cost allowances, would all be of value to the Aquaculturist once an operation has developed to a "going concern" status. However, during the infancy of the industry tax incentives must be introduced to attract capital to the industry. Vehicles such as 50% investment tax credit with pass-through privileges upon investing, in the Aquaculture industry would be sufficient to attract equity to the industry through start-up and development stages. Otherwise, without the flow-through privileges, current tax incentive programs will not help until the industry is in a developed state.

In summary, when Aquaculture is an afterthought to the above programs, and is being considered for funding beside other applications from older, well-established industries, it is easy to recognize why a Loan Officer would favour the established industry applicants in light of the investment perceptions reviewed in the previous section.

In theory the above programs should cover a range of requirements, as Fralick (2) p. 64 points out, but the difficulty is as he stated... "However, the crucial question is whether the grower/processor can fit the working criteria of the review boards who pass judgement on the proposals."

The answer is that not only are the programs too restrictive related to "inside the farm 'gate'" and working capital, but that Aquaculture because of its infancy, cannot stand up to relative projects from established industries. Therefore, there must be established separate funding programs and tax incentives for Aquaculture/Mariculture, otherwise a shortage of working capital and capital for inside the farm gate will continue.

MARKETS AND COMPETITIVE FOODSTUFFS

The subject of markets has its own special subsection in this Conference, but because of the importance of markets and marketing to economic viability, a few emphatic statements must be made here.

In Canada, too little has been done to be innovative in marketing seafood products. Very little has been done to develop the perception that the consumer dicates the success of the product line. Traditionally we have stuck with the same product, the same package, the same quality (poor, by international standards) for years. Little interaction has developed along the distribution and marketing channels. This was verified by the Wong report **(7)**, and further verified (at least on the west coast), by comments like "it is very difficult to get fresh seafood in Vancouver, a coastal city," or, "the good seafood restaurants in Vancouver can be numbered on one hand."

However, even in light of the above, the outlook for seafood looks attractive. Wong (p. 306, table 29) is predicting a 44% increase in per capita demand for fish and shellfish between 1979 and 1985. That means that we are in a position to replace other foodstuffs with proper promotion.

If we as Canadians do not service the domestic market, others will, such as Norwegian exports of pen-raised salmon to the USA. If we do service our domestic market, why not try to supply export markets as well? A well-planned and well-developed Aquaculture industry will give us this opportunity. In Aquaculture there is a much better chance of providing the key marketing components; those of quality and continuity of supply. Both of these aspects are more controlled in Aquaculture than in the wild fishery. From the quality point of view, you can designate meat quality through controlled diets, size is easily controlled with fresh daily delivery, and these are all major advantages. As far as continuity of supply, a person's chance of controlled marketing of a farmed salmon or off-bottom cultured oysters, are far higher than a seek fishery.

Finally, as Aquaculture goes through its development stage, costs of production should drop drastically, whereas we can expect the wild fishery and other food systems that are already developed (such as the poultry industry), to have cost increases. This will make Aquaculture very cost competitive with other foodstuffs.

ECONOMIC STRATEGY

In summary, we have identified that the microeconomic models to date indicate economic feasibility in the traditional sense, however, we have recognized that the paper models have their limitations and should not be construed as valid for long-term viability. We have further outlined that it may be necessary to expand economic analysis to include macroeconomics and social welfare economics. Further, in comparison to other production systems, subsidies should be neutralized in comparisons.

We have found that, on the surface, investment potential is received in a lukewarm manner, primarily based upon previous track records. We have found that the assistance programs which exist are unlikely to help Aquaculturists because of the infancy of the industry. However, market potential appears to be large.

In summary, although potential appears to exist, virtually no progress has been made over the last 10 to 15 years, and if we continue to proceed in this historical fashion Aquaculture will continue to develop slowly.

How can this be Changed?

ESTABLISH A LEAD AGENCY

At the World Mariculture Society Conference in Washington, D.C., in January, 1983, three prominent politicians in the U.S. spoke and relayed a message that in their respective areas, (Hawaii, Alaska, and Louisiana), until a lead agency for Aquaculture was established, very little was accomplished. The industry has a tough enough time in developing, let alone trying to encourage government.

ESTABLISH THE MOST LIKELY SPECIES

Through species workshops and by developing microeconomic models, the species with the highest probability of economic success should be selected. Consideration of biological aspects, culture systems, production costs, markets and price supply probabilities, should be considered in depth, and a development plan laid out for each species.

DO COMMERCIAL PILOT PROJECTS

Once the species with the highest probability of commercial success is/are selected, then commercial scale pilot projects should be undertaken. The emphasis must be on assisting existing industrial participants, and not government or academics in isolation. These pilot projects must be set up with the best support teams possible. The teams should include biologists, engineers, accountants, and marketing support. These support teams will make up for the lack of infrastructure. As the projects develop, the requirements for research, improvements in culture systems, cost improvement areas, etc., will become very evident, and resources must be provided to optimize each area.

The results of these projects will provide hard information on production costs and will produce products which can be used for market testing.

DO MARKET SURVEYS WITH REAL PRODUCT

Suggestions have been made that before effort is put into developing an Aquaculture industry, international market surveys must be undertaken. It is my suggestion that it is not necessary to survey world markets until we identify our most likely species. Further, in most cases we already have knowledge of the world markets, because the wild fishery has, and is, in the process of marketing internationally. We know, for instance, that we are net importers of oysters; that the predicted scallop demand exceeds the projected supply. Broad information is already available for the most likely species.

What we do not know is that if the product, through mariculture production, is available more readily, or offered in a consistent size or package that caters to the consumer, what the demand may be.

This type of information can be obtained by conducting taste panels and market surveys with product from the pilot projects. This will produce information that is many magnitudes more accurate than market surveys without using the real product.

ESTABLISH GOVERNMENT ASSISTANCE PROGRAMS FOR AQUACULTURE

As pointed out earlier, assistance programs that now exist either miss the requirement, or Aquaculturists are in competition with more established industries and thus lose out. Specific funding and incentive programs related to Aquaculture must be established to provide working capital inside the farm gate, and to encourage investment in the industry.

Benefits of an Expanded Mariculture Industry

USE OF EXISTING OVER-CAPITALIZATION

The fishing industry in Canada is currently overcapitalized in both fishing vessels and in processing plant capacity. Processors are going into receivership on a regular basis, and vessels are being repossessed. The major problem is a limited resource. The Federal government is considering large buy-back programs which entail the expenditure of vast amounts of capital. With mariculture we have an opportunity to make use of the overcapitalization. For instance, if we were able to develop a program on a species similar to the Japanese experience with scallops, large numbers of the excess fishing vessels coud be switched from fishing to mariculture. Further, the productive capability of the ocean as a cultured basis far exceeds that of the natural fisheries, thus with success in the mariculture industry the excess processing plant capacity could be used.

The only remaining new capital requirements would be for the purchase of the grow-out systems.

ENHANCEMENT OF FISH HABITAT

In the mariculture development in Japan a beneficial spin-off effect has resulted. It has been shown that in the areas of cultured species the fish habitat has improved, thus creating an opportunity for development of a greater fishing harvest.

LOW ENERGY REQUIREMENTS

Mariculture has (in the format that is being proposed in Canada) a low energy requirement for the production of food.

REPLACE IMPORTS

We are currently importing shellfish that could be produced locally. For instance, there is a ready market for $3 to $5 million annually in smoked and canned oysters alone.

INCREASE EXPORTS:

The forecasts for demands of shellfish indicate that an optimistic export potential exists.

EMPLOYMENT CREATION:

Mariculture, because of the nature and location of the work, tends to attract people in the age bracket of 18 to 35 years. This age group is one of the highest unemployment categories. Employment could be created for people who are in the high unemployment areas such as the small centres along the coasts. Fishermen who are being displaced could find employment. Fishermen could use mariculture to supplement low incomes by working on mariculture when fishing seasons are closed. In addition, there are numerous marine biologists that have difficulty finding employment in their chosen field, who could be employed. In Japan, revenue generated from oysters and scallops alone is in excess of $500 million, and creates employment in excess of 13 000.

A rigorously developed long-run strategy has to be evolved for each candidate species. In order to accomplish this, extensive cooperation must be developed between industry, governments, and research institutions. Adequate programs will have to be instituted to fund the planning, research, and commercialization. The bridge to be crossed is too long and expensive for an individual entrepreneur, and left to government and consultants alone the Aquaculture Monetary Black Hole will continue to consume taxpayers' dollars with little results.

However, if properly approached, success will result. An industry employing thousands and contributing to the Gross National Product in excess of the wild fisheries, will develop — at least on the West Coast.

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